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SPECIAL FEATURES

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TRANSACTIONS

of the

American Society for Steel Treating

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HARMONY

IT HAS been stated that it is the little things in life that count and such we believe to be the case. Take any of the single wires forming the supporting cables for the Brooklyn bridge and you will observe that it is the size of a piano wire, and consequently does not in anyway indicate a strength sufficient for the work it has to do. Nevertheless, when thousands of these small wires are wound and twisted together we have the combined strength of all, and a strength that is capable of holding up and supporting the tremendous weight of the bridge.

An so it is in any industry, the single individual although playing an important part in a plant could not, working alone, be able to carry out the undertaking, yet with a great many men making up a large complex organization, each of them has their own individual strength and power and the capacity of exercising it in the proper direction. Altogether they present a united front to all conditions that arise and thus are capable of accomplishing wonderful results through unity and harmony.

When Harry S. New, the Postmaster General, declared the other day "the best work can be done only under harmonious conditions," he was uttering a rather good general law. There is no use of trying to play the trombone in the orchestra unless you and all the other players are in harmony. Like Al Jolson used to sing, "You can't play every instrument in the orchestra, but at least you can keep in tune." There is no joy in the home unless there is harmony. You do not have to be beautiful, nor clever, nor interesting, nor even intelligent to get along, but you do have to be harmonious. There is no success in business, there is no fun in a game unless there is harmony. The beauty about harmony is that it does not mean equality,

for in harmony there is a place for the greater and the less, and the wise and the ignorant, the good and the less good. We do not have to be indispensable, but we do have to fit in.

SPIRIT

NO MATTER what you do, you put something of yourself into it.

There are those who put all that they are in whatever they do—and then there are those who merely divide their interests and give and work by half or less. It is the spirit in which you do things that counts more than anything else. Not only for the one you may work for, but for yourself. We can never leave ourselves. Not for a second: Neglect one part of your work and you neglect yourself.

It is the living spirit within us that urges us on that tells us the way to better things, that urges us to rise when we fall and to look up instead of down.

You may make a very bad blunder—but if your spirit was working in the right direction, that blunder can be easily passed by. It is inspiring to meet some people. They seem to have a wonderful inward spirit that is working every minute in their lives. No matter under what condition you meet them, that same even spirit is there. We can all have a happy spirit if we will. It is largely a matter of proper viewpoint and the right consideration of others.

Influence is a wonderful force. And it is the fine spirit that you carry around with you that gives you influence.

WORKERS

IN EVERY chapter there will always be a few individuals because of their own inclination and because they are so situated as to be able to devote time to the interests of the Society who will stand out pre-eminently as instrumental in carrying the message of the Society to those who should be interested, and in this way obtain a large number of memberships for the Society and local chapter. In this connection one of the best examples of conscientious effort and ability directed along this line is exemplified by Norman C. Einwechter of the firm Einwechter & Wyeth, 512 Commerce Street, Philadelphia,

who as a member of the Philadelphia chapter and as a prominent member of the Membership Committee of that chapter has been largely instrumental in contributing to the 80 per cent increase in membership the Philadelphia Chapter has had since September of last year.

Mr. Einwechter very modestly declines credit for any exceptional ability in securing members stating that his entire efforts in the matter have been solely for the benefit and advancement of the man who was actually working in heat treating steel, so that by his becoming a member of the Society he might learn what the outside was doing in new methods, new equipment and new processes in the art and sciences of the manufacture and working of metals. Mr. Einwechter found that practically every corporation interested in the lines followed by the Society, that investigates the teaching the local chapters are advancing to them and their employers, is very glad to support the educational and progressive organization of the A. S. S. T. in promulgating and disseminating practical knowledge of the treatment of metals.

Mr. Einwechter stands very high in the estimation of the members of the Philadelphia Chapter, and they are constantly presenting to him their appreciation of his excellent work during the past year, realizing Mr. Einwechter has placed in his work on the Membership Committee the same enthusiam and energy that has made the firm with whom he is connected such a prominent one in the Philadelphia territory.

In the Hartford Chapter much interest and congratulations are being given to Don Stacks, a consulting metallurgist in that territory, and because of his ability to circulate among the trade has been instrumental in bringing the Hartford Chapter well up in the membership contest by securing sustaining and individual members. Mr. Stacks has always been an enthusiastic member of the Chapter and his work is bringing to him added recognition as to his ability.

FIFTH ANNUAL CONVENTION

PROMISING to invade the Steel City with real enthusiam, members of the A. S. S. T. from every important American and Canadian industrial center will gather at Pittsburgh the second week in October, for the annual convention of the A. S. S. T.

is to be notable not only for its size but for its representation in every phase of steel manufacture and treatment of metals and for the details and consideration that will be given to concrete problems. Organization details are working in a satisfactory manner, and the program is taking shape quite rapidly.

Identification certificates for use of members and guests in securing railroad rate reduction will be sent out to all members of the Society from the National headquarters, and also to others planning to attend the Convention who send in requests for these certificates. Over 6000 will be issued. Certificates are issued on the basis of official requests only, except so far as the members of the Society are concerned. Added to this list to whom railroad certificates will be sent must be added the totals of guests from points near Pittsburgh who will not avail themselves of the rate or those who will desire to return home another way, or to continue their journey to another city.

Pittsburgh has declared itself out to win the National pennant for the best and biggest and most enjoyable National Convention the A. S. S. T. has ever held. Radio invitations will be forecasted inviting the general public to attend the convention and exposition. The Pittsburgh committee co-operating with the National President, T. D. Lynch, and the National Secretary have been working for months in their efforts to present the most comprehensive and complete program ever offered at an annual convention. Morning sessions will be given over to general meetings, while the afternoons will be devoted to round table sessions and symposiums.

The speakers before the general morning sessions will include many men of nation wide reputation. Not only will America be predominantly represented in the program but the convention itself will take on an international aspect inasmuch as papers are to be presented by representative men of England, France, Japan and Germany.

The entertaining program has not been overlooked, every moment not taken up with business meetings or visiting exhibits will be given over to pleasure. The 250 members of the Pittsburgh chapter are exerting every effort to give the visiting members and guests the time of their life. The right hand of good fellowship will be extended. Every minute that isn't taken up

with constructive thought will be devoted to seeing that the visitors carry away a proper impression of the hospitality of Pittsburgh.

The exposition which is to be one of the big features of the fifth annual convention of the A. S. S. T. will open at Monday noon, October 8, and all of the visiting guests and members will participate in the opening exercises. The exposition at Detroit last year was by far the largest that had been held by the Society, yet there has been thirty per cent more space taken for the Pittsburgh show than for the Detroit exposition, and it is confidently believed that by the time the exposition doors are open every available foot of space will be engaged. The exposition has grown to such size and the requests for space have been so heavy that it will be necessary to use two floors in Pittsburgh in order to accomodate the firms desiring to present their products for examination and inspection. On the sub-floor will be located the meeting room of the Society where the afternoon round tables and sessions will be held. A novel feature has been added to the sub-floor in order to make it especially attractive and as a point of interest for the members, so the entire floor is to be given an Egyptian setting and there also is to be located an exact replica of King Tut's Tomb. This combined with the oriental music and other features now being planned will all contribute to adding a spirit of good fellowship and enthusiam to the exposition. At least 20,000 are expected to visit the convention and exposition.

The members of the various Pittsburgh committees who are working so diligently for the success of the 1923 convention and exposition are as follows:

GENERAL CHAIRMAN

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H. L. Walker, Secretary General Committee, 1521 Monterey Street, Pittsburgh.

HOTEL RESERVATIONS FOR THE CONVENTION

IN ORDER that our members and guests may be well taken care of during the time of the annual convention of the Society to be held in Pittsburgh, October 8 to 12 inclusive, we are publishing in this issue of the TRANSACTIONS a list of the

WILLIAM PENN HOTEL
Convention Headquarters

hotels at Pittsburgh so that you can make your reservations immediately and thus be sure of accomodations.

In writing to the hotel please state the price and kind of room you wish, and request them to acknowledge your communication confirming the reservation and price.

The hotels in Pittsburgh will be packed to their utmost

capacity to take care of the enormous number who will visit the city during the convention, consequently, we cannot urge you too strongly to make your reservations at once. It will be necessary for you to state that you are attending the convention of the American Society for Steel Treating, otherwise your reservation may be refused.

In case you have difficulty in securing the accomodations you wish, a communication addressed to the chairman of the hotels committee, R. E. Polk, chief industrial engineer, Equitable Gas Company, Pittsburgh, Pa., will receive prompt attention and your wishes will be taken care of.

List of Pittsburgh Hotels

William Penn

(Headquarters)

375	Rooms	with	bath,	2	persons,	Rate	$3.50-5.00	each
375	Rooms	with	bath,	1	person,	Rate	4.00-8.00	

Fort Pitt

190	Rooms	with	bath,	2	persons,	Rate	$2.50-5.00	each
100	Rooms	without	bath,	2	persons,	Rate	2.50	each
190	Rooms	with	bath,	1	person,	Rate	3.50-9.00	
100	Rooms	without	bath,	1	person,	Rate	3.00	

Hotel Henry

12	Rooms	with	bath,	4	persons,	Rate	$2.50	each
12	Rooms	with	bath,	2	persons,	Rate	3.00	each
24	Rooms	with	bath,	1	person,	Rate	4.00	up

Anderson Hotel

20	Rooms	with	bath,	4	persons,	Rate	$2.50	each
24	Rooms	without	bath,	4	persons,	Rate	2.00	each
10	Rooms	without	bath,	2	persons,	Rate	2.50	each
20	Rooms	without	bath,	1	person,	Rate	3.00	

General Forbes

17	Rooms	with	bath,	4	persons,	Rate	$2.00	each
9	Rooms	with	bath,	2	persons,	Rate	3.00	each
24	Rooms	without	bath,	2	persons,	Rate	1.50	each
25	Rooms	with	bath,	1	person,	Rate	4.00	up

Seventh Avenue Hotel

14	Rooms	with	bath,	4	persons,	Rate	$2.50-3.00	each
10	Rooms	with	bath,	2	persons,	Rate	2.50-3.00	each
20	Rooms	without	bath,	2	persons,	Rate	2.00-2.50	each

Pittsburgh Natatorium

(For gentlemen only)

175 Rooms, with swimming pool, cots, 1 person, Rate $2.00

Monongahela House

10	Rooms	with bath,	2 persons,	Rate	$3 00	each
40	Rooms	without bath,	2 persons,	Rate	2.00	each

Schenley Hotel

5	Rooms	with bath,	4 persons,	Rate	$3.00	each
10	Rooms	with bath,	2 persons,	Rate	4.00	each
10	Rooms	without bath,	2 persons,	Rate	3.00	each
10	Rooms	with bath,	1 person,	Rate	7.00	
10	Rooms	without bath,	1 person,	Rate	4.00	

Rittenhouse Hotel

25	Rooms	with bath,	2 persons,	Rate	$2.00-3.00	each
20	Rooms	with bath,	1 person,	Rate	3.00-4.00	

Y. M. C. A., East Liberty

10	Rooms	without bath,	1 person,	Rate	$2.00

Negri Hotel

25	Rooms,	with bath,	1 person,	Rate	$3.00

New Sixth Avenue

15	Rooms	with bath,	2 persons,	Rate	$3.00-4.00	each
15	Rooms	without bath,	2 persons,	Rate	2.50-3.00	each
10	Rooms	with bath,	1 person,	Rate	3.00	
5	Rooms	without bath,	1 person,	Rate	2 00-3.00	

Chatham Hotel

5	Rooms	with bath,	4 persons,	Rate	$2.00	each
20	Rooms	with bath,	2 persons,	Rate	3.00-5.00	each
20	Rooms	without bath,	2 persons,	Rate	2.50-3.00	each
15	Rooms	with bath,	1 person,	Rate	3.00	

EASTERN SECTIONAL MEETING WELL ATTENDED

THE Eastern Sectional meeting held in Bethlehem, Pa., June 14 and 15, 1923 under the auspices of the Lehigh Valley chapter of the society proved to be a most successful and interesting meeting from every viewpoint, and was probably the most successful sectional meeting that has been held.

The papers program consisted of two technical sessions, the first being held Thursday afternoon, June 14 at 1:30 p.m. in the University room of the Hotel Bethlehem. The meeting was called to order by A. P. Spooner, metallurgist of the Bethlehem Steel Company and chairman of the Lehigh Valley chapter of the A. S. S. T. who introduced John J. Crowe, metallurgist of Philadelphia Navy Yards, who acted as chairman for this meeting.

An address of welcome was given by Archibald Johnson, vice president of the Bethlehem Steel Company who in a very

cordial manner welcomed the members and guests of the various chapters of the American Society for Steel Treating to Bethlehem. Following Mr. Johnson's talk, President T. D. Lynch remarked briefly in reference to the activities of the American Society for Steel Treating.

The first technical paper of this session was presented by Dr. F. C. Langenberg of the Watertown Arsenal, entitled "Behavior of Metals Under Normal and Sub-Normal Temperatures". The second paper by F. R. Palmer of the Carpenter Steel Company, Reading, Pa., entitled, "Equalization of Internal and External Strains in Tool Steel". The third paper by B. F. Shepherd, Ingersoll-Rand Company, was entitled "Case Hardening". Each of these papers treated their subjects in a most capable manner, bringing forth considerable interesting and valuable discussion. These papers will be published in early issues of TRANSACTIONS.

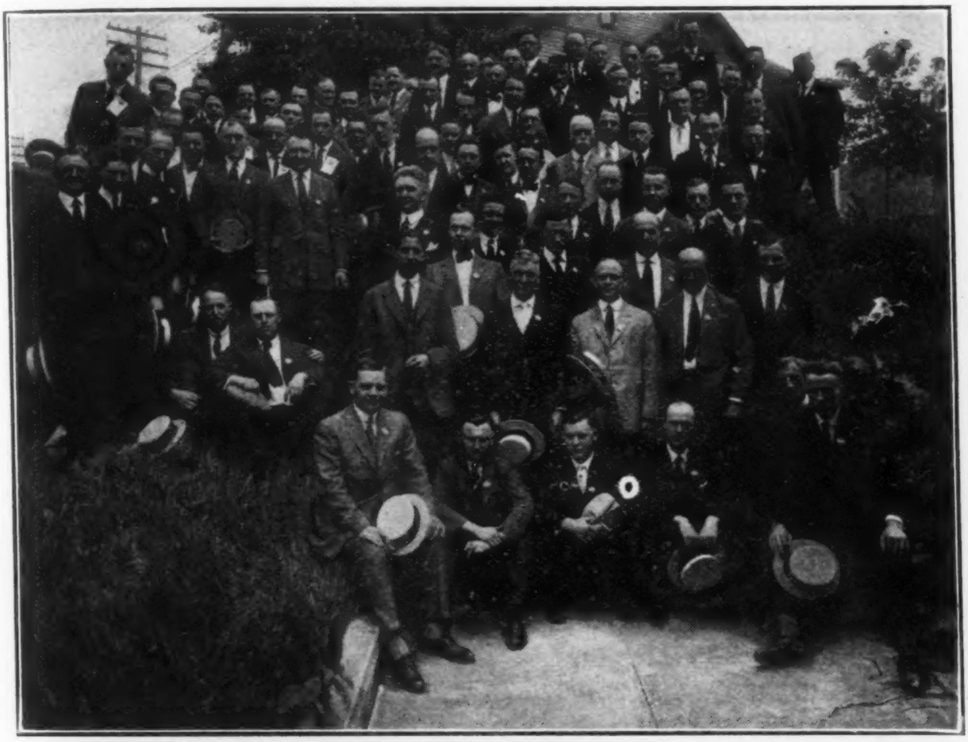
The evening program consisted of a dinner and entertainment for members, guests and ladies in the ball room of the Hotel Bethlehem. The speaker for this dinner meeting was Dr. E. J. Cattell of Philadelphia who gave a very interesting talk on "America's Progress".

The Friday morning program consisted of an inspection trip through the plants of the Bethlehem Steel Company. The visitors assembled at the Battery building of the steel company at 8:45 for the inspection of the permanent exhibit of products made by the steel company and then proceeded through the various plants of the steel mills. This trip covered the points of interest which were outlined in the May issue of TRANSACTIONS. Luncheon was served at one o'clock in the dining room of the main office of the Bethlehem Steel Company and from there the members proceeded to Drown hall of Lehigh university where the second technical session was held.

Under the chairmanship of Sam Tour this session was called to order and was first addressed by Dr. C. R. Richards, president of Lehigh university who greeted most cordially the members of the society, welcoming them to Lehigh university. The first technical paper entitled "Practical Metallography" was presented by R. H. Christ of the Bethlehem Steel Company, and the second paper entitled "The Develop-

ments of Heat Resisting Metals" was given by Victor Hybinette of the British America Nickel Company of Wilmington. Each of these papers brought forth many interesting features in reference to their subjects and were well discussed after their presentation.

The visiting ladies were well entertained by various trips around Bethlehem including an automobile trip to Delaware



Group of Members Who Attended the Eastern Sectional Meeting Assembled at the Battery Building of the Bethlehem Steel Company, which was the Starting Point of the Plant Inspection Trip.

Water Gap and the historical points of interest in and about Bethlehem. More than 150 members, of the various chapters, but principally those from the eastern chapters attended this meeting and as evidenced by the enthusiasm of all of these members, this sectional meeting was highly successful and bids well for the continued success of the sectional meetings of which this was the fourth.

CRYSTALLIZATION OF IRON AND ITS ALLOYS-I*

By Albert Sauveur

Abstract

This paper describes the dendritic crystallization of iron carbon alloys and its further transformations and calls attention to the importance of its study. It is shown that the properties of steel depend upon its microstructure and its persistent dendritic segregation, and that the latter is not affected by the usual heat treatments, while hot working causes deformation of the segregated areas and results in directional properties. The action of certain reagents in revealing dendritic segregation is explained as well as the relation existing between the dendritic or solidification structure and its microstructure.

INTRODUCTION

A TINY drop of liquid iron or of steel should, on solidifying, if it obeyed only the laws of crystallography, be converted into a regular octahedron (Fig. 1). Such perfect crystals with faultless geometrical outlines are called idiomorphic crystals. The octahedron is a form belonging to the cubic or regular (isometric) system of crystallization. Iron and steel like most metals, crystallize in the cubic system. Iron, moreover, when it solidifies, exists in the allotropic condition known as gamma iron. The octahedron, therefore, is the crystalline form of gamma iron. The gradual growth of octahedral crystals has been studied and it has been observed that the main axes are formed first, and that this is followed in quick succession by the appearance of secondary and ternary axes and finally by the filling up of the interstices between the axes, (Fig. 2). If the liquid could be removed before this filling up takes place, we would obtain what is sometimes described as skeleton crystals (Fig. 3).

Crystals grow through the successive addition of small crystalline units symmetrically arranged according to the system of crystalliation to which they belong. If these units are cubic their

*As it is the author's intention to publish other papers on this same subject, he has, for ease in later referring to it, numbered this article: I.

A paper to be presented at the annual convention of the Society, Pittsburgh, October 8-12. The author is professer of metallurgy, Harvard University, Cambridge, Mass. Written discussion of this paper is invited.

corresponding faces will lie in parallel planes. This is called the orientation of the crystals and constancy of orientation is a property of all crystals. Because of this crystalline orientation, crystals possess direction of easy rupture known as cleavage planes. Cubic crystals have three cleavage planes, ABC, DEF,

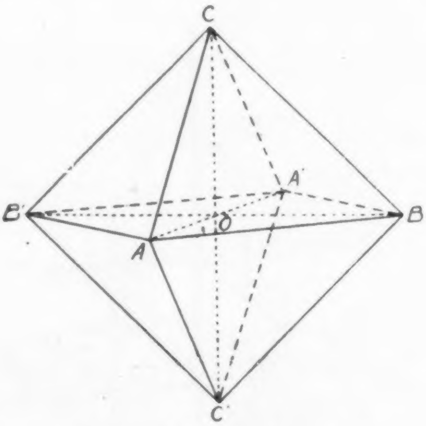


Fig. 1—Regular Octahedron. Perfect Crystals Conforming to such Faultless Geometric Outlines are called Idiomorphic Crystals.

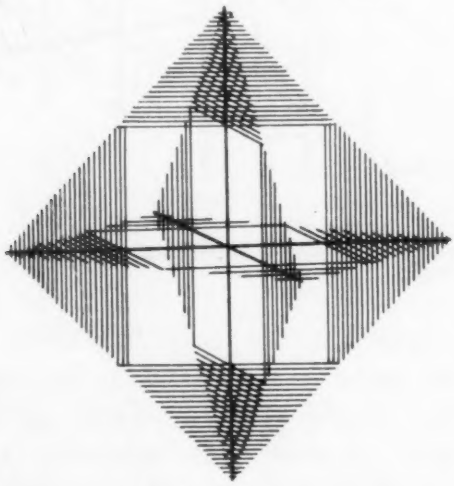


Fig. 2—Gradual Growth of Octahedral Crystals. From Belaiew's "Crystallization of Metals", (After Knop).

and GHI, Fig. 4, parallel to the three sets of faces of the solid. Constancy of crystalline orientation imparts also unlike properties in different directions, that is, causes anisotropy. In the case of the octahedron one may, following Howe, conceive the crystalline units to be cubic, (Fig. 5). Such octahedral crystal would then

have three planes of cleavage parallel to one of the three pairs of faces of the small cubes and four planes parallel to one of the four pairs of faces of the octahedron.

A tiny drop of liquid iron or of liquid steel will not, however, assume, on solidifying, the external form of an octahedron because of contact with the support on which it is solidifying, and

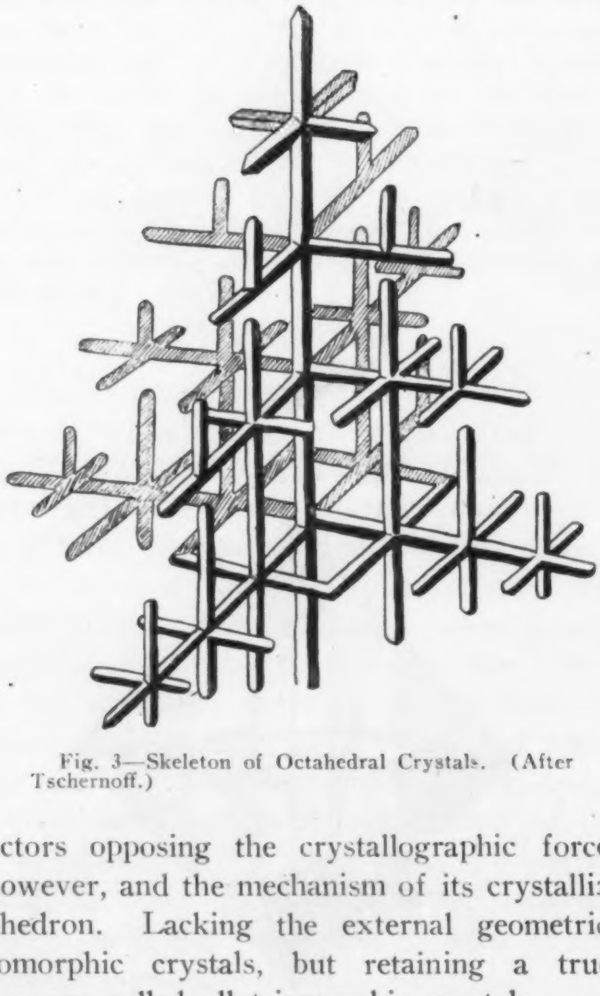


Fig. 3—Skeleton of Octahedral Crystals. (After Tschernoff.)

of other factors opposing the crystallographic forces. It does crystallize, however, and the mechanism of its crystallization is that of the octahedron. Lacking the external geometrical form of perfect, idiomorphic crystals, but retaining a true crystalline structure, they are called allotriomorphic crystals.

If a considerable mass of liquid iron or of liquid steel could be conceived to exist without its container, suspended in space in the form of a liquid sphere or cube, and if crystallization started at the center of the solid and proceeded with equal velocity and without hindrance in all directions, the result would be a single very large idimorphic crystal, a perfect octahedron. Liquid metals, however, must of necessity be held in containers, the form

of which they retain after solidification, notwithstanding the crystallizing forces which would cause them to assume octahedral forms. Assuming that the crystallization of liquid steel in its mold could proceed from one center only, and could complete itself

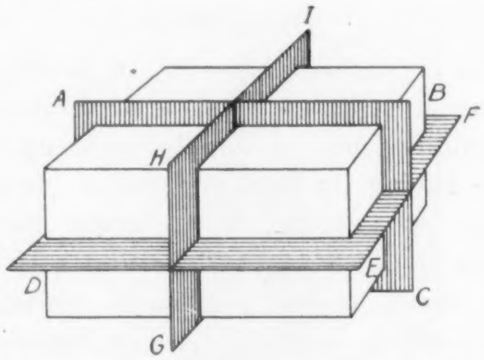


Fig. 4—Cleavage Planes of a Cubic Crystal (After Mellor). Cubic Crystals have Three Cleavage Planes as shown by ABC, DEF, and GHI, Parallel to the Three Sets of Faces of the Solid.

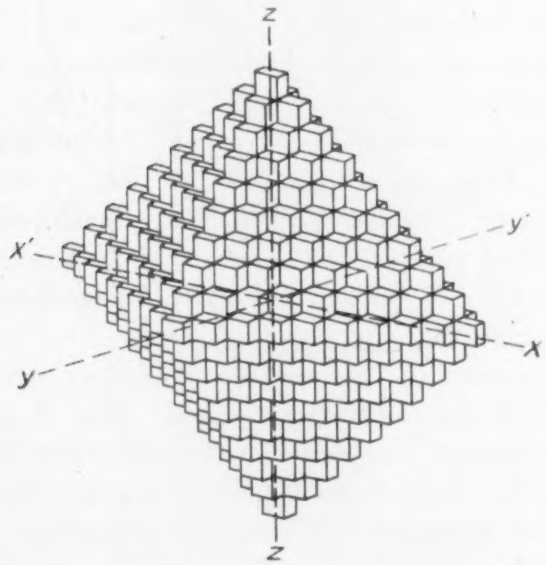


Fig. 5—Octahedral Crystal Composed of Small Cubes (After H. M. Howe). Such an Octahedral Crystal would have Three Planes of Cleavage Parallel to One of the Three Pairs of Faces of the Small Cubes and Four Planes Parallel to One of the Four Pairs of Faces of the Octahedron.

without change of orientation, it would be octahedral in its habit and would result in a single, very large allotriomorphic crystal, having for its external form the internal form of the mold.

Masses of steel made up of but one crystal would probably be very brittle because of the readiness with which crystals can be ruptured along their cleavage planes. They would also inherit the directional properties of single crystals. They would be anisotropic.

Dendrites

When a metal crystallizes, however, in passing from the liquid to the solid state, crystallization proceeds from many centers or nuclei and the solidified mass is finally made up of a great many crystals each one having its own orientation. In the case of iron and steel, if the crystallizing forces could have free play, a perfect octahedron would be formed around each nucleus and the solidified metal would consist of many juxtaposed octahedra. Opposing and disturbing factors intervene, however, such as surface tension and contact with neighboring crystals likewise, in process of formation, which prevent the crystals from assuming regular geometrical forms. In other words, allotriomorphic and not idiomorphic crystals are produced. The mechanism of their formation remains, however, octahedral in character. The disturbing factors mentioned above cause each individual octahedral growth to increase more rapidly in some directions than in others and generally, elongated crystallites known as "dendrites" are obtained as in Fig. 6. They are also called, because of their appearance, "pine" or "fir-tree" crystals. Such fully developed dendrites are generally found in the "pipes" of large ingots hanging to the roof, like stalactites, (Fig. 7). Belaiew describes dendrites as elongated aggregates of octahedra.

Solidified masses of iron or steel, therefore, are made up of a great many dendrites closely interlocked, (Fig. 8 and 9). While each crystal possesses directional properties, while it is anisotropic, the mass as a whole may be considered isotropic, possessing uniform properties in all directions. Directional properties may indeed be imparted to steel as later explained, but this is not due to the anisotropy of the small crystals of which it is made up. It should be borne in mind that the number, size, and form of these crystals, and, therefore, the properties of the castings, will necessarily be influenced by a number of factors, such as composition, initial casting temperature, rate of solidification, etc. It should be further observed that the cooling action of the walls of the mold has a tendency to impart a "radial" or "columnar" structure to

the casting (Fig. 10 and 11), the main axes of the external dendrites being normal to the walls.

It should not be expected that the physical properties of such a casting will be uniform throughout. Test pieces cut from the

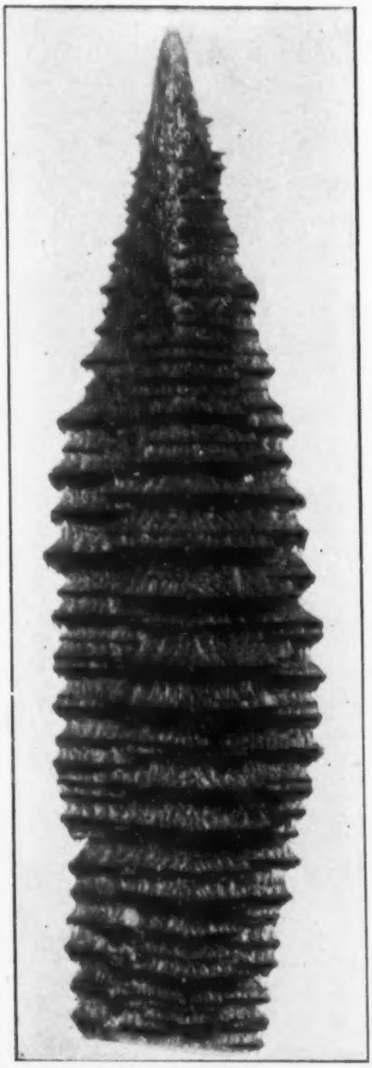


Fig. 6—Steel Dendrite. (Reduced ½.) Such Formations are also Called "Pine" or "Fir-Tree" Crystals and are Generally Found in the Pipes of Large Ingots, Hanging from the Roof like Stalactites.

portions of the casting having a radial dendritic structure will of necessity exhibit different properties from those possessed by test pieces cut from the central portion where the dendritic growth

has not been so powerfully influenced by the cooling action of the walls. Steel castings are necessarily structurally heterogeneous.

When it will be shown that the dendritic segregation which accompanies the formation of dendrites cannot be effaced by sub-

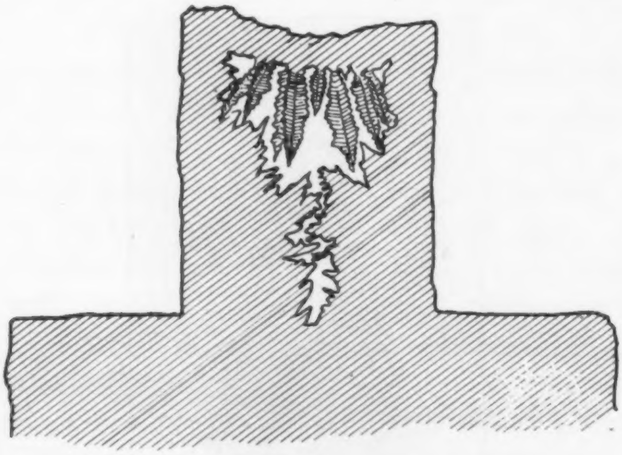


Fig. 7—Steel Dendrites in Sinking Head of Large Ingot. (After Tschernoff.)

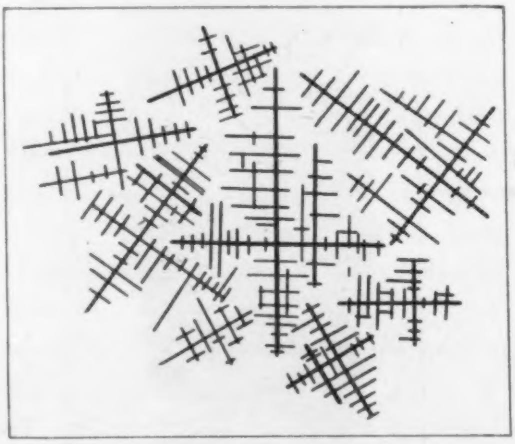


Fig. 8—Dendritic Segregation in Steel. (After Tscernoff.) Solidified Masses of Iron or Steel are Made Up of a Great Many Dendrites Closely Interlocked.

sequent heat treatments, and that its influence persists even after mechanical working, the importance of its study will be readily appreciated.

Mechanism of Dendritic Growth

Let us assume a single dendritic crystal in process of formation, Fig. 12. It is believed on very good ground that the primary

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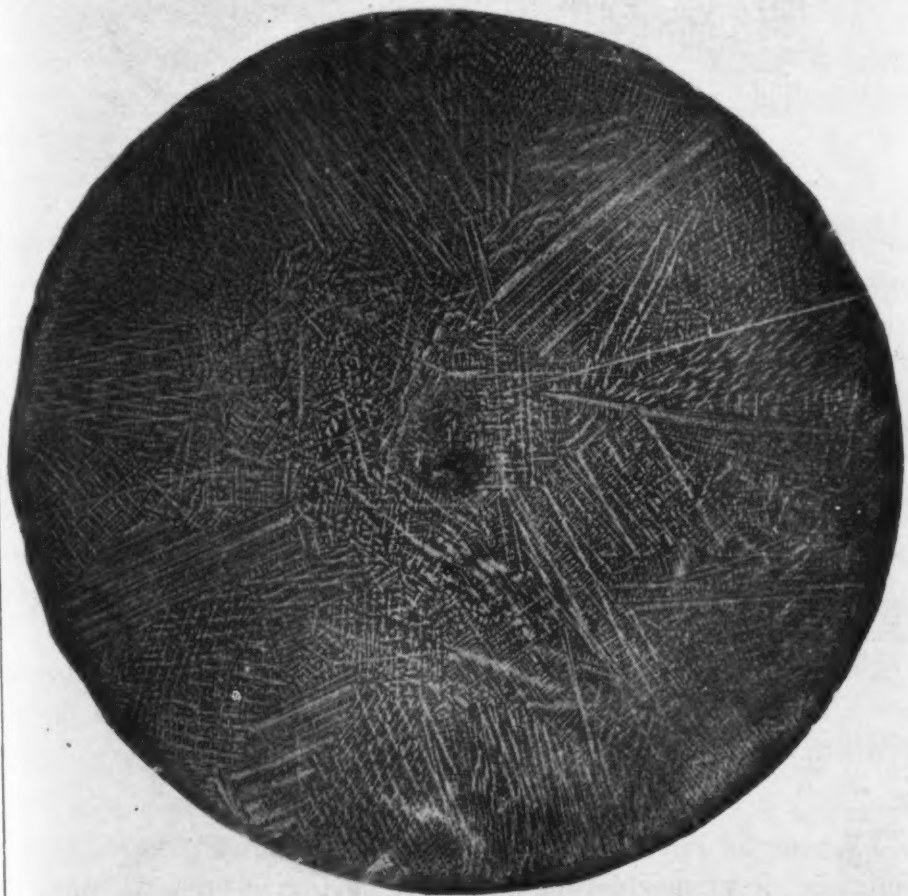

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Fig. 9—Dendritic Segregation in Steel, Magnified 2 Diameters. (By V. N. Krivobok in author's laboratory.)

Fig. 10—Radial Dendritic Crystallization in Steel. (After Tschernoff.) The Cooling Action of the Walls of the Mold has a Tendency to Impart a Radial or Columnar Structure to the Casting. The Main Axes of the External Dendrites are Normal to the Walls.

axis forms first and that this is followed quickly by the appearance of secondary and ternary axes. These axes grow and thicken through gradual deposition of cubic or octahedral particles of soild metal until, finally, the interstices between them are filled up in a like manner and the dendrite is completed. Its external shape will necessarily be influenced by eventual contact with neigh-

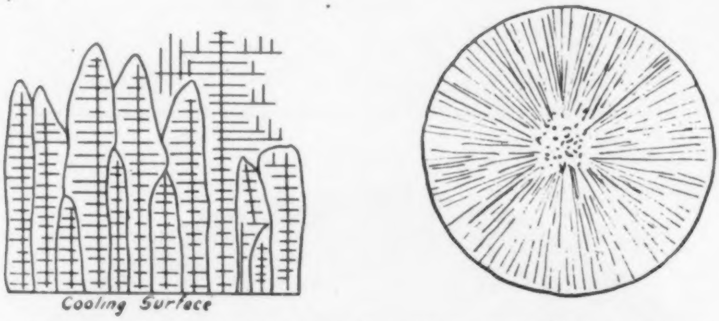

Fig. 11—Sketch Showing the Formation of Radial or Columnar Structure in Steel Castings (After Tschernoff).

boring dendritic growths and boundary lines should exist between them. (Fig. 13). It is, however, only occasionally that these boundary lines can be brought out as in Fig. 14. If the iron is chemically pure, the dendrite will necessarily be *chemically homogeneous* in all its parts, and will form at a *constant temperature,* namely, at the solidification point of iron. If we accept Rosenhain's theory in regard to the existence of an amorphous film or cement between crystals formed from the liquid state, then we must assume that each dendrite is enclosed within an amorphous membrane or bag. While the amorphous theory has been brilliantly conceived and vigorously upheld and while it explains satisfactorily many phenomena, it should not be accepted as proven fact. Let us employ it as a useful tool, and be ready to discard it whenever a better one is at hand.

Detection of Dendritic Growth

Whenever it is possible for crystals to grow freely, without hindrance from neighboring growths, as for instance in pipes of large ingots (Fig. 7), the dendrtic character of the crystallization of iron and steel is clearly revealed. A mass of steel, however, is composed of closely interlocked dendrites and to study its crystallization we must examine polished and suitably treated plane surfaces. Such sections should have the appearance shown in Fig. 9.

When the dendritic character of the crystalization of steel is clearly revealed, these dendrites and their boundaries are generally so large that they can be observed with the naked eye. The structure is then said to be *macroscopic,* to distinguish it from structures so small as to require the use of a microscope for their detection, that is, from *microscopic* structure. We talk, therefore, of macrostructure and of microstructure. The terms dendritic structure and macrostructure, however, should not be used indifferently as having the same meaning because a dendritic structure is not necessarily macroscopic, nor a macrostructure necessarily dendritic. The dendritic structure of iron and steel may properly be called "primary structure" and the large grains enclosed within the dendritic boundaries "primary grains." They are generally macroscopic in size, hence, we may also talk of macro and of micrograins.

The possibility of bringing out the dendritic structure of steel through some suitable treatment of polished sections should be considered. It would seem as if there should be no difficulty in revealing the existence of boundaries between adjoining dendrites because, even in chemically pure metals, those boundaries, if they do not consist of amorphous cement, mark at least changes of crystalline orientation. As already mentioned, however, the existence of these boundaries are often very difficult to bring out. An etching treatment to be effective must necessarily be selective in its action, and in order that it may be selective, the sample under study must be chemically or physically heterogeneous. In the absence of such heterogeneity, selective action by the reagent is impossible and the structure remains hidden. Assuming a dendrite, therefore, perfectly homogeneous in all its parts, physically and chemically, its structure cannot be brought out by etching methods. It should be the case with chemically pure iron. When so called chemically pure iron is considered, however, it is well to remember that such purity is hardly obtainable and that a very small proportion of impurity, possibly little more than a trace, may suffice to produce in the dendrite the necessary heterogeneity required for the selective action of the reagent. It should be further considered that while iron may be reported free, or practically free, from the ordinary impurities it may still contain some gases held in solution and this may suffice to produce dendritic heterogeneity.

Dendrites of Solid Solution

Let us assume a metal or metalloid M′ dissolved in a metal M and let us assume the soluble component M′ to have a lower melting point than the solvent M. As soon as the solidification range of the alloy is reached, dendrites begin to form at many centers, or nuclei, throughout the cooling mass. Let us consider a single dendrite and follow the mechanism of its formation, (Fig. 12). The main axis of the crystal will be the first one to appear

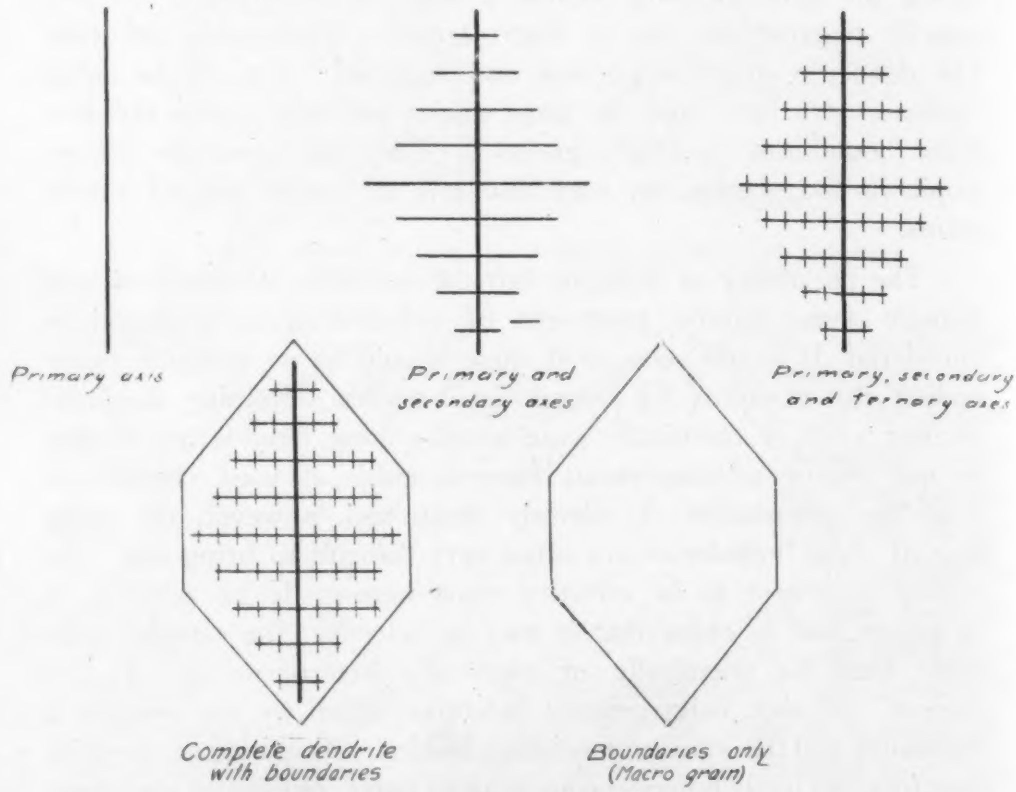

Fig. 12—Diagrammatic Sketch Showing the Growth of a Dendrite. The Axes Grow and Thicken Through Gradual Deposition of Cubic or Octahedral Particles of Solid Metal until Finally the Interstices between them are Filled Up in a Like Manner and the Dendrite is Completed.

and it will be considerably richer in the high melting-point constituent, that is, in the metal M, than the liquid from which it forms. Secondary and ternary axes will follow in turn *as the temperature of the alloy continues to fall* and these will contain more of the more fusible metal than the main axis but still less of it than the molten metal. Finally, the interstices between the axes will solidify and will contain more of the low melting point metal M′ than

the axes. In other words, the formation of a dendrite of a solid solution implies a gradual segregation of the low melting point constituent as the dendrite grows, the portion of last solidification being the richest in that constituent. The boundaries between adjoining crystalline growths, since they are the last to solidify, should contain more of the fusible constituent than any portion of the dendrites themselves. If the boundaries between the dendrites are occupied, as some believe, by amorphous metal or cement, it seems obvious that this amorphous material must be much richer in the low melting point metal than the original alloy. We lack

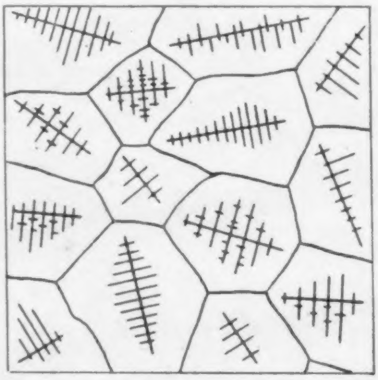

Fig. 13—Dendrites and Boundaries. (After Desch.) The External Shape will Necessarily be Influenced by Eventual Contact with Neighboring Dendritic Growths and Boundary Lines Should Exist Between Them.

experimental evidence, however, that this is actually the case. The mechanism of the formation of solid solutions, therefore, necessarily implies the production of chemically heterogeneous dendrites. The segregation producing this heterogeneity may be called *dendritic segregation.*

While this heterogeneous dendrite is in the process of formation, however, the phenomenon of diffusion asserts itself and tends to produce chemical homogeneity through the migration of some metal M from the parts in which it abounds to portions deficient in that constituent and in a like manner migration of some of the metal M′ from the fillings to the axes. This diffusion continues probably on cooling below solidification and is promoted by a slow solidification, long sojourn at high temperatures and slow cooling. Complete diffusion would efface altogether the dendritic segregation and a chemically homogeneous dendrite would be ob-

tained. It would then be impossible as previously explained to disclose by etching methods the dendritic crystallization since selective action could not take place. Impossibility of bringing out a dendritic structure in an iron or steel casting must be considered as an indication of a chemically pure metal or of a solid solution freed by diffusion from dendritic segregation. Dendritic segregation always occurs when a solid solution forms and complete diffusion is very rare. While diffusion may decrease to a considerable extent

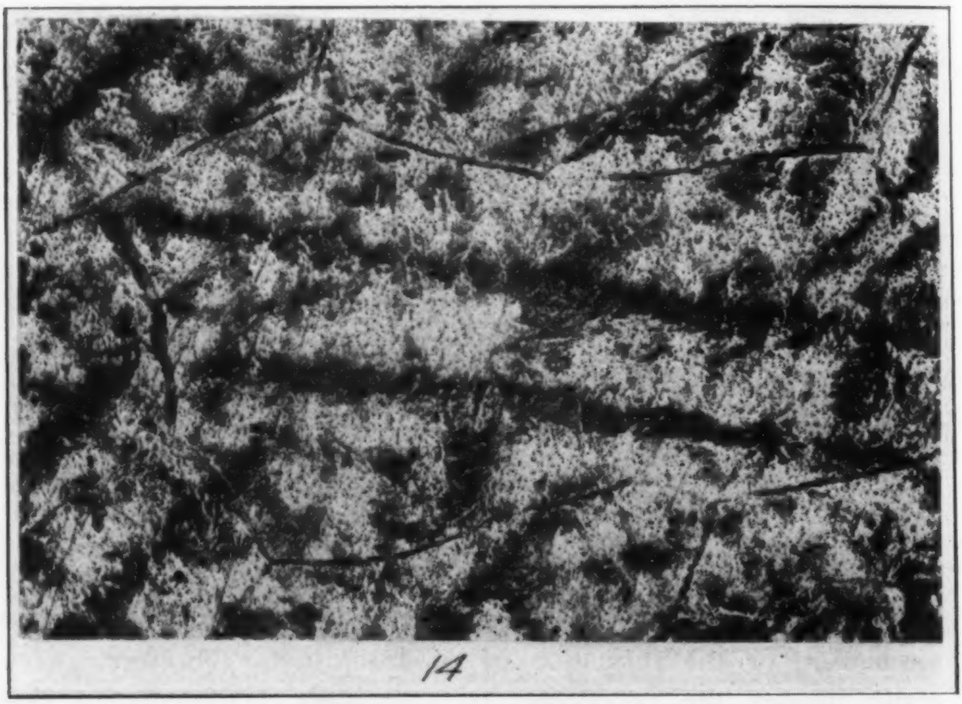

Fig. 14—Dendrites and Boundaries. ×74. (By V. N. Krivobok in the Author's Laboratory.)

dendritic segregation it does not efface it completely and the dendrites at room temperature remain chemically heterogeneous.

If the dendrites of a solid solution are chemically heterogeneous, that is, if their axes have a different chemical composition from the fillings, it becomes possible to bring out the dendritic structure through the selective action of suitable etching reagents. In the case of iron-carbon alloys, for instance, some copper etching reagents may cause a deposition of copper on the axes while the fillings remain unaffected, (Fig. 9).

Dendritic Segregation in Iron-Carbon Alloys

The fact that the dendritic structure of steel can generally be readily revealed by suitable etching treatments is an indication that the dendrites of steel are chemically heterogeneous, that is, that the dendritic segregation has not been completely eliminated by subsequent diffusion. It is important to know what constituents are chiefly responsible for this dendritic segregation. We may confine our attention to the three constituents which form with iron, solid solutions, namely, carbon, phosphorus and silicon. Stead claimed long ago that phosphorus was chiefly, if not altogether, responsible for dendritic segregation. This view was generally accepted and is still the prevailing one today.

According to Stead the main axes contain comparatively little phosphorus, the secondary and ternary axes a larger amount, and the fillings a still greater quantity. While diffusion may cause a decrease of phosphorus segregation, it cannot erase it and the dendrites at room temperature remain heterogeneous as to phosphorus distribution. On etching polished sections with some copper reagents, copper is deposited on the axes which are comparatively free from phosphorus, while it fails to be deposited on the fillings which contain considerably more phosphorus. Dendritic structure is in this way revealed. Stead claims further that phosphorus expels carbon from the portions of the dendrites where the former predominates into portions containing little phosphorus, that is, it expels carbon from the fillings and concentrates it in the axes.

The following experiment affords a striking confirmation of the claims that phosphorus produces persistent dendritic segregation and that in passing through the thermal critical range, carbon migrates from the portions rich in phosphorus, namely the fillings, to segregate in the axes, which contains relatively little phosphorus. Using armco iron, a steel ingot was prepared containing 0.17 per cent carbon and 0.39 per cent phosphorus. It was found that on etching this steel with the usual solution of nitric acid and alcohol, a very clear dendritic structure was revealed, (Fig. 15). Upon closer investigations, it was discovered that the axes were made of pearlite while the fillings, undoubtedly rich in phosphorus, were free from carbon (Figs. 16 and 17); hence the possibility of bringing out a dendritic structure by nitric acid etching. After

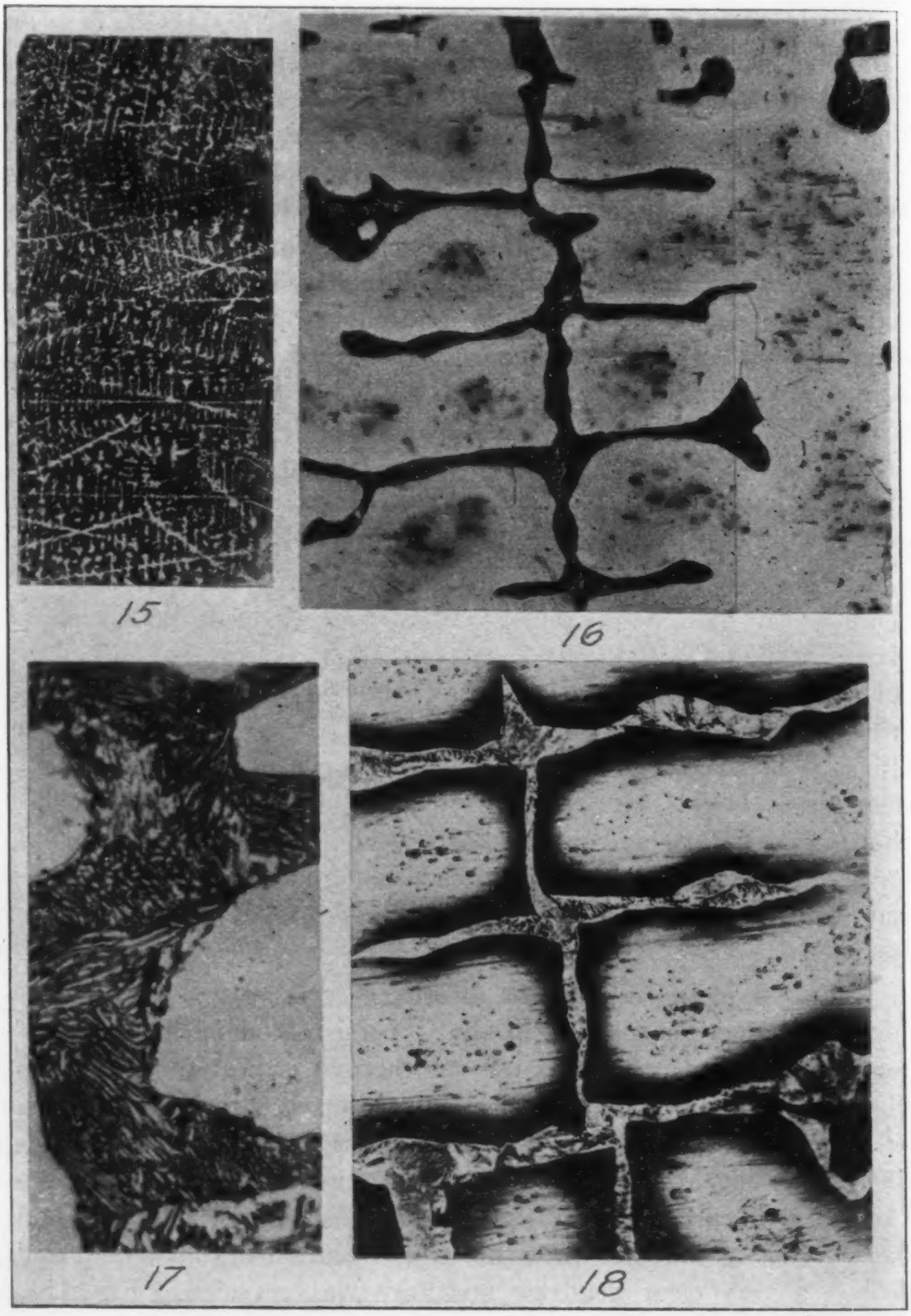

Fig. 15—Dendritic Segregations Revealed by Etching with Nitric Acid. ×4. FIG. 16—Same as Fig. 15. ×—65; Fig. 17—Same as Fig. 15. ×—1000. Figs. 16 and 17 Show that the Axes Were Made of Pearlite, while the Fillings Undoubtedly Rich in Phosphorus, Were Free from Carbon, Hence the Possibility of Bringing Out the Dendritic Structure by Nitric Acid Etching. Fig. 18—Same as Fig. 15. ×—85. Etched with LeChatelier Reagent. After treatment with LeChatelier Reagent a Similar Dendritic Structure is Obtained Through the Copper Being Deposited on the Phosphorus-free Ferrite of the Pearlite Axes. The Fillings Were not Affected. (Micrographs by V. D. Krivobok in author's laboratory.) Analysis; Carbon, 0.17 per cent, Phosphorus, 0.39 per cent.

treatment with the Le Chatelier reagent, a similar dendritic structure is obtained (Fig. 18) through the copper having deposited on the phosphorus-free ferrite plates of the pearlitic axes, while the impure ferrite constituting the fillings was not affected, except for the ferrite immediately surrounding the pearlitic axes where it is freer from phosphorus, thus producing an intense coring effect.

The conclusions seem warranted that, on solidifying, the phosphorus, by locating in the fillings of the dendrites, produced intense and peristent dendritic segregation and that on cooling through the thermal critical range, the phosphorus caused the carbon to leave the fillings and to collect in the axes resulting in pearlitic axes and ferrite fillings. While we have here a strong indication that phosphorus produces persistent dendritic segregation and that it is capable of expelling carbon from the regions where the former abounds, it would not be wise to infer that phosphorus alone is responsible for persistent dendritic segregation, because such segregation has been found repeatedly in steel practically free from phosphorus. We are led to inquire, therefore, what other elements besides phosphorus are capable of producing it.

Persistent dendritic segregation caused by phosphorus results, on working the steel, in the formation of ferrite bands or ghosts (the drawn fillings) rich in phosphorus and inclusions and in pearlitic bands (the drawn axes) as shown in Fig. 20.

Le Chatelier has challenged Stead's contention that persistent dendritic segregation in steel was always due to the presence of phosphorus. In his opinion oxygen is the element responsible for it. He finds that when steel containing phosphorus is melted in hydrogen and is therefore free or nearly free from oxygen, a dendritic structure cannot be brought out by etching, which indicates absence of dendritic segregation. On the other hand, steel free from phosphorus but melted with free access of air and therefore containing oxygen is found to be dendritic after etching. Additional experimental evidences are needed in order to strengthen or to disprove the accuracy of this contention.

Disregarding for the moment what element or elements are responsible for persistent dendritic segregation and therefore for the possibility of revealing by etching the dendritic character of the crystallization of steel, it may be considered as firmly established that after solidification all steels are composed of closely

interlocked dendrites (Fig. 9). If we refer to Fig. 19 in which the steel portion of the iron-carbon diagram has been reproduced, it will be noted that the dendrites formed as the alloy cools from its liquidus AB to its solidus ACD. In the complete absence of

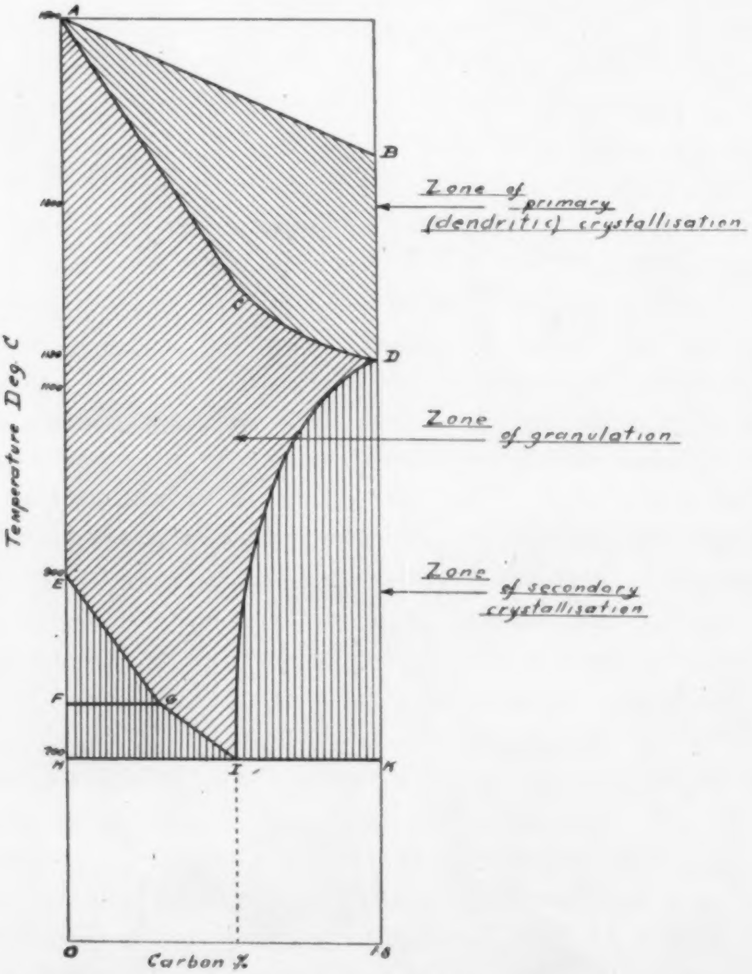

Fig. 19.—Steel Portion of the Iron-Carbon Equilibrium Diagram. It will be Noted that the Dendrites Form as the Alloy Cools from Its Liquidus AB to Its Solidus ACD. In the Complete Absence of Carbon these Dendrites Necessarily Form at a Constant Temperature, Namely at the Melting Point of Pure Iron. As the Carbon Increases the Distance Between Liquidus and Solidus Increases and Becomes Maximum at 1.00 per cent Carbon. From 1.00 to 1.80 per cent Carbon it Remains Practically the Same Length.

carbon these dendrites necessarily form at a constant temperature, namely, at the melting point of pure iron. As the carbon increases the distance between liquidus and solidus, that is, the solidification range, increases and becomes maximum at about

1.00 per cent carbon. From 1.00 to 1.80 per cent carbon it remains practically of the same length. The question may reasonably be asked whether the length of the solidification range has any influence on the size of the dendrites—whether a long range of solidification promotes the formation of more or of fewer dendrites; whether the number of dendrites in eutectoid steel, for instance, with its wide range of solidification is greater or less than the number of dendrites in hypo-eutectoid steel? While there is good ground for believing that the dendrites of eutectoid steel and of hyper-eutectoid steel are smaller than those of hypo-eutectoid steel doubt still exists as to whether this difference is due to differences in the solidification ranges of the steels or to differences in their carbon content.

Granulation of Dendrites

If the dendritic structure of steel resulting from solidification underwent no modification or transformation on further cooling, all steels at room temperature would consist of interlocked austenitic dendrites. Although their properties would undoubtedly vary somewhat with their carbon content and the size and form of the dendrites, they would possess the characteristics of the solid solution austenite. They would be very resistant to abrasion, very difficult to machine and they would be nonmagnetic. They would resemble Hadfield's manganese steel and would have a limited range of application.

On cooling from the solidus to room temperature, however, very important transformations occur which impart entirely new properties to the metal. When a sample of carbonless iron or of steel containing a very small amount of carbon is allowed to cool slowly from the liquid state to room temperature, it is found on microscopical examination, after etching with the usual reagents, to be made up of small polyhedral crystals or micrograins. If a little carbon is present, small particles of pearlite will also be formed. (Figs. 21 and 22).

From the foregoing description of the formation of dendrites and of macrograins on solidification it seems evident that these small micrograins must have formed after solidification; that they result from a breaking down of the dendrites. This theory, advanced by Belaiew gives us the only acceptable explanation of the relation between the microstructure of steel and its dendritic

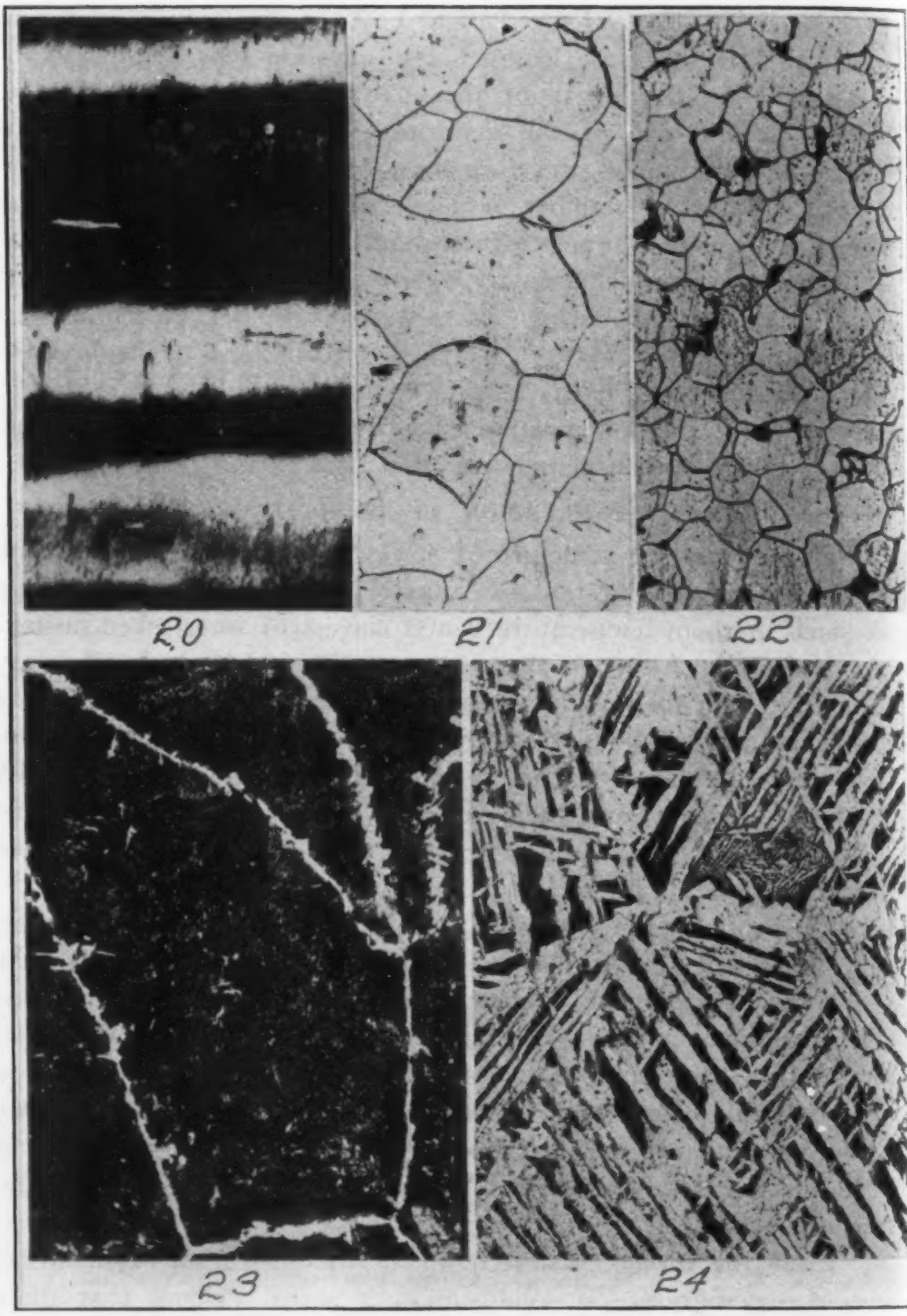

FIG. 20—Banded Structure in Rolled Steel Caused by Persistent Dendritic Phosphorus Segregation. ×—100. Fig. 21—Polyhedral Microstructure of Carbonless Iron ×—125. (By D. C. Lee in author's laboratory); Fig. 22—Polyhedral Microstructure of Low Carbon Steel. ×—100. (By E. L. Chao in author's laboratory); Fig. 23—Network Structure in Hypo-eutectoid Steel Casting. ×—65. Fig. 24—Cleavage Structure in Hypo-eutectoid Steel Casting, Showing the Well Known Widmanstatten Structure. Etched with Nitric Acid. ×—100. (Figs. 23 and 24 by V. D. Krivobok. in author's laboratory.)

structure, generally of macro size. Belaiew argues that when steel cools from the solidus to the thermal critical range the dendrites and the large grains constituted by the boundaries of those dendrites undergo a process of granulation. The granulation zone corresponds to the area ACDIGE of the equilibrium diagram (Fig. 19). In cooling through this zone each dendrite breaks up into a number of small (micro) grains, each having its own crystalline orientation. Since they form above the thermal critical range, they are austenitic micrograins. *Such a process necessarily implies the disappearance of the dendrite as a crystalline unit.* In other words, a large allotriomorphic crystal necessarily of constant crystalline orientation throughout has been transformed into a number of small allotriomorphic crystals every one with its own orientation and, therefore, independent crystalline existence.

An examination of the zone of granulation, that is, of the area ACDIGE, of the equilibrium diagram reveals the fact that the width of that zone varies greatly in different steel. For carbonless iron it extends from about 1500 to 900 degrees Cent., (2730 to 1690 degrees Fahr.), covering a range of 600 degrees Cent. (1110 degrees Fahr.). As the carbon increases the granulation zone decreases slightly. For eutectoid steel, it still covers a range of 500 degrees Cent. (930 degrees Fahr.) (from 1200 to 700 degrees Cent.) As the eutectoid point is passed, however, the granulation zone decreases very rapidly. With 1.50 per cent carbon it is reduced to 1.30 degrees Cent. (1130 to 1000 degrees Cent.) With 1.80 per cent carbon the granulation zone disappears. Hypo-eutectoid and eutectoid steels, therefore, have wide granulation zones (500 to 600 degrees Cent.), while in hyper-eutectoid steel the granulation zone is rapidly narrowed, being finally reduced to zero. It is pertinent to ask whether for like cooling conditions the extent of the granulation zone affects the number of the resulting grains; whether the grains of hypo-eutectoid steel should be for that reason more or less numerous than the grains resulting from the granulation of hyper-eutectoid steel. We naturally infer that the absence of a granulation range in steel containing 1.80 per cent carbon must signify that the dendrites of steel of that composition do not break up into independent crystalline grains.

The nature of the boundaries surrounding the micro-grains resulting from the crystallographic breaking up of the primary

dendrites should be considered. Rosenhain in formulating and explaining his amorphous cement theory contends that amorphous iron exists at the boundaries of the micrograins on the ground that they coincide with the last films of metal to solidify. If the granulation theory of Belaiew is correct, Rosenhain must be wrong, since these small grains were not formed during solidificaton but *below* solidification. Amorphous iron should exist at the boundaries surrounding the dendrites according to Rosenhain, but not, at least not for like reasons, at the boundaries between the micrograins. It might be argued that amorphous cement exists also at the boundaries between the micrograins on the ground that when a crystallographic form is transformed into another crystallographic form the substance must first assume the amorphous state and that this state is retained at the boundaries, the final amorphous films surrounding the grains being too thin to assume the crystalline orientation of either of the adjoining grains.

Seeing that the dendrites formed during solidification are entirely destroyed through the granulation they undergo between the solidus and the thermal critical range, it is at first a source of surprise that we should ever be able to bring out a dendritic structure in steel at room temperature. The answer to the apparent enigma is that *the possibility of revealing a dendritic structure through etching treatment does not depend upon the existence of dendrites but upon the existence of dendritic segregation and that while granulation obliterates the dendrites it does not affect dendritic segregation.* The segregating element, whatever it may be, occupies the same portions of the original dendrite even after the latter has undergone granulation. Treatment with the copper reagent, for instance, still results in a deposit of copper on those portions of the polished surface once occupied by dendritic axes since those portions are as free from the segregating element as they were before granulation. The result is a dendritic structure generally of macro-size brought out by suitable reagents and resulting from dendritic segregation and a micro-structure resulting from the granulation of the dendrites .

From the close examination of a great many samples treated with the Le Chatelier reagent the author reached the conclusion that *copper is deposited on ferrite only and that when both ferrite rich in the segregating element and ferrite poor in that element,*

for brevity of speech impure and pure ferrite, are present, it is on the pure ferrite only that copper is deposited. In the absence of ferrite, in austenitic and martensitic steels, for instance, it is quite impossible to develop a dendrtic structure by means of the Le Chatelier reagent. It does not follow, however, that dendritic segregation does not exist in these steels and that it cannot be revealed by other reagents or other treatments.

Secondary Crystallization and Microstructure

It has been shown that steel on cooling from the liquid state to its thermal critical range solidifies through the formation of many dendrites, that these dendrites undergo granulation on cooling below

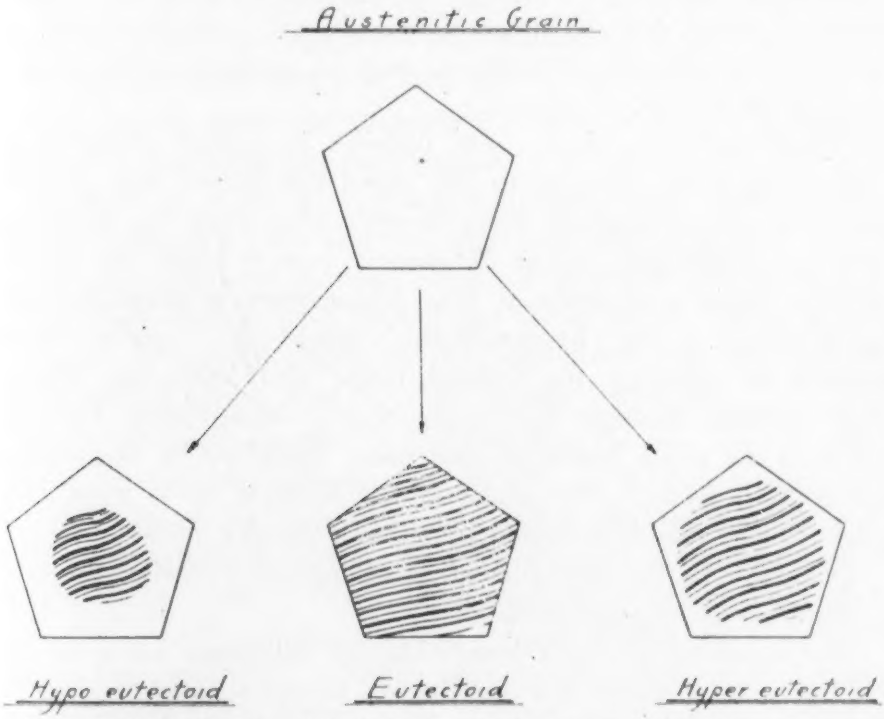

Fig. 25—Diagrammatic Sketch of the Austenitic Grain Passing Through Its Thermal Critical Range.

the solidus but that the dendritic segregation which necessarily accompanies the formation of solid solutions persists. On reaching the thermal critical range therefore all steels are made up of grains generally of micro-size resulting from the granulation of austenitic dendrites generally of macro-size, with the possible exception of steel containing 1.80 per cent carbon which has no granulation range.

We should now consider what takes place when the steel cools through its thermal critical range to room temperature. The mechanism of that transformation is well known. If the steel is of eutectoid composition such a grain of austenite is converted into a grain of pearlite at the single critical point of that steel, (Fig. 25). If the steel is hypo-eutectoid a certain amount of ferrite separates from the solid, austenitic solution on entering the critical range until the remaining austenite finally of eutectoid composition is transformed into pearlite at the bottom of the range that is at the Ar_1 point. If the steel is hyper-eutectoid, it is cementite which separates in a like fashion in cooling through the range. In Fig. 25 it has been assumed that the entire amount of ferrite or of cementite is rejected to the boundaries. It will soon be shown that some of the separating constituents may be retained in the cleavage planes of the grains.

When carbonless iron cools through its upper critical point, it passes from the gamma to the alpha condition* and since the cube is the crystallographic form of alpha iron while the octahedron is the crystallographic form of gamma iron it must be assumed that each grain undergoes at that temperature a crystallographic transformation. In hypo-eutectoid steel the ferrite which separates on entering the critical range and keeps on separating on cooling through the range, passes immediately from the gamma to the alpha condition and must therefore be made up of small cubic crystals. That alpha ferrite is made up of small cubic crystals can be readily revealed by suitable etching tests.

Belaiew calls the transformation taking place during the critical range, secondary crystallization.

The speed of cooling through the critical range has a marked effect upon the location and distribution of the separating constituent, ferrite or cementite, and therefore upon the final structure of the casting. Speeds of cooling sufficiently slow to permit complete separation of the excess ferrite or cementite and final transformation of the remaining austenite into pearlite are alone considered here. Bealiew believes that if the cooling through the range be extremely slow the separating constituent is given the necessary time to reach the boundaries of the crystalline grains and distinct network structures are obtained, (Fig. 23). If on the contrary the cooling is too rapid to permit this migration the separating element

*The author purposely disregards here the possibility of gamma iron transforming into beta iron, lest he draw the fire of the anti-beta contingent.

will be retained to a greater extent in the crystallographic planes of the octahedral crystals and the well known Widmanstätten or cleavage structure will result. (Fig. 24).

According to Belaiew a very slow cooling through the granulation zone promotes the formation of the Widmanstätten type of structure on quick cooling through the critical thermal range. In spite of Colonel Belaiew's brilliant defense of his conception of the formation of the Widmanstätten structure, it fails to fully satisfy. It is difficult at the outset to oppose his theory because he wins both ways. When the Widmanstätten structure is obtained after rapid cooling through the zone of secondary crystallization, it is in accordance with his conception, and when such structure results from slow cooling through the zone, it likewise conforms with his theory on the ground that it is then due to undercooling.

It is hardly necessary to insist on the fact that steel castings exhibiting the network structure cannot be expected to have properties identical to those of castings exhibiting the Widmanstätten structure, although identical in chemical composition. In the majority of cases steel castings exhibit a structure having some of the characteristics of both types, that is, in which the separating constituent is situated partly at the boundaries and partly at the cleavage planes. This may be called "mixte" structure.

It is not unreasonable to suppose that the size of the grains formed during granulation and which is probably dependent upon the size of the dendrites may influence the final structure, that is, may induce or oppose the network type of structure or the Widmanstätten type. Will a large austentitic grain for instance result in a Widmanstätten structure more readily than a smaller grain of the same steel? Seeing that in a large grain the separating constituent has a longer way to travel to reach the boundary, it seems that this might be the case. Assuming this reasoning to be sound, Widmanstätten structures should form more readily in hypo-eutectoid than in hyper-eutectoid steels, since the former for like cooling conditions have larger grains.

Many queries of a practical nature come to mind. Will a network structure respond to the annealing treatment more readily than the Widmanstätten structure and should it therefore be promoted in our castings? It is not likely that both behave in a similar manner; one must be preferable and should be induced and

while one type might be more advantageous in castings that are not to be annealed, the other type may be more desirable in castings to be annealed. This opens up an important field of investigation.

In high carbon steel the zone of granulation is very narrow and when the metal contains 1.80 per cent carbon it is non-existent, (Fig. 19). High carbon steels, therefore, should have very small austenitic grain on reaching their critical range ID, (Fig. 19). While it would seem as if this must result in the separating cementite readily reaching the boundaries and forming network structures, Belaiew believes that in such high carbon steel the cementite has a tendency to separate parallel to the crystallographic axes of the dendrites, giving rise to structures that he calls "large crystals." In the extreme case of an alloy containing 1.80 per cent carbon, since the metal does not granulate at all, as soon as it has solidified, (D, Fig. 19), cementite begins to be rejected by the cooling dendrite and locates itself along the crystallographic axes of that dendrite.

To further clarify and sum up the foregoing discussion let us follow the solidification and cooling to room temperature of carbonless iron, hypo-eutectoid steel, eutectoid steel, hyper-eutectoid steel and steel containing 1.80 per cent carbon.

Solidification of Carbonless Iron

Carbonless iron solidifies at 1530 degrees Cent. (2785 degrees Fahr.) when dendrites of gamma iron* are formed. The dimensions of the dendrites probably depend on the rate of cooling, a rapid solidification causing the appearance of a greater number of nuclei and therefore of smaller dendrites. If the iron contains some impurity subject to persistent dendritic segregation, chemically heterogeneous dendrites will result and their detection will be possible at room temperature through the selective action of a suitable reagent. If it does not contain such impurities, the dendrites will be chemically homogeneous and it will not be possible to reveal by etching the dendritic character of the solidification of the metal. Accepting Rosenhain's theory, the boundaries between adjoining dendritic growths should be occupied by amorphous iron. In cooling from the solidification point to 900 degrees Cent. (1690 degrees Fahr.) every dendrite breaks up into

*The author intentionally ignores the possibility of the dendrites consisting of delta iron before granulation and of gamma iron after granulation.

small (micro) grains of gamma iron. The number and, therefore, dimensions of these grains probably depend upon the rate of cooling through the granulation zone and on the size of the dendrites which in turn depends upon the rate of solidification. On reaching the upper critical point of pure iron, at about 900 degrees Cent. (1690 degrees Fahr.), each grain of gamma iron is converted into a grain of beta iron, or according to those who deny the existence of beta iron, into a grain of alpha iron, accompanied by a transformation of the octahedral units of gamma iron into the cubic units of alpha iron.

At room temperature, carbonless iron consists of a mass of polyhedral micro-grains of alpha iron which have been formed *in situ* at the point Ar_3 through the transformation of as many grains of gamma iron, themselves formed, during the granulation zone through the crystallographic breaking up of the dendrites resulting from solidification. If persistent dendritic segregation exists treatment with the Le Chatelier reagent will result in copper being deposited on the ferrite of the axes because it contains less of the segregated element or elements than the ferrite of the fillings. In this way, although the dendrites themselves no longer exist, the dendritic character of the crystallization of iron stands revealed.

Solidification of Hypo-eutectoid Steel

Let us now follow the solidification and cooling to room temperature of a hypo-eutectoid steel. Let us assume that it contains 0.50 per cent carbon. The solidification of such steel will begin at about 1475 degrees Cent. (2685 degrees Fahr.) and will be complete at 1300 degrees Cent. (2370 degrees Fahr.), Fig. 19). It will proceed, therefore, as the temperature is falling and will cover a range of some 175 degrees Cent. (345 degrees Fahr.). Crystallization starts at many centers or nuclei and dendrites are formed, their number and size depending on the speed of solidification, a greater speed probably inducing a greater number of nuclei and, therefore, a greater number of dendrites necessarily of smaller size. These dendrites consist of a solid solution of carbon in gamma iron, that is, of austenite. In cooling through the granulation zone which extends from 1300 to 750 degrees Cent. (2370-1380 degrees Fahr.), these austenitic dendrites generally of macro-size are converted into small micro-grains of austenite, each one with its own orientation and, therefore,

independent crystalline existence. The number of these grains and, consequently, their size likewise will depend upon the size of the original dendrites and the rate of cooling through the granulation zone. It seems reasonable to assume that a rapid cooling through the zone of granulation will induce the formation of a greater number of grains necessarily of smaller dimensions. At a temperature of about 750 degrees Cent. (1380 degrees Fahr.,) the steel now composed of many austenitic grains of micro-size enters its critical range which, following Belaiew, we may call zone of secondary crystallization. At about 690 degrees Cent. (1275 degrees Fahr.) it emerges from that zone transformed into an aggregate of ferrite and cementite. As previously explained and according to Belaiew, if the cooling through that range has been sufficiently slow, a network structure will result, whereas a faster cooling tends to produce the Widmanstätten type of structure or a combination of both types which we may call "mixte" structure. If the grains formed in the granulation zone are large, a Widmanstätten structure should be produced more readily because of the greater distance to be covered by the separating ferrite in reaching the boundaries in order to form network structures and a slow cooling through the granulation zone should promote the formation of large austenitic grains.

If the dendritic segregation which necessarily accompanies the formation of solid solutions has persisted, a treatment with the Le Chatelier reagent will cause a deposition of copper on the free ferrite present in the axes as well as upon the ferrite plates of the pearlite in these axes, while the free ferrite and the pearlite-ferrite occupying the fillings will not be coated. This is in conformity with the belief previously expressed that copper deposits only on ferrite and that when both pure and impure ferrite are present, it deposits selectively on the pure ferrite and not on the impure ferrite. It follows that although the dendrites no longer exist at room temperature, the presence of dendritic segregation makes it possible to reveal the fact that on solidifying, the steel crystallized in the form of dendrites.

Solidification of Hyper-Eutectoid Steel

Let us now consider a hyper-eutectoid steel containing 1.5

per cent carbon. It solidifies on cooling from 1400 to 1150 degrees Cent. (2750-2100 degrees Fahr.) It is then made up of austenitic dendrites, the number and dimensions of which will depend upon the rate of solidification as previously explained. The granulation zone of this steel extends from 1150 to 1050 degrees Cent. (2100-1920 degrees Fahr.), and in passing through it, each dendrite breaks up into a number of austenitic grains, generally of micro-size, a fast cooling probably inducing the formation of a greater number of grains and consequently decreasing their size. At 1050 degrees Cent. (1920 degrees Fahr.) the steel enters its thermal critical range or range of secondary crystallization. At the point Ar_1 about 690 degrees Cent. (1275 degrees Fahr.) it emerges from that range converted into an aggregate of pearlite and cementite, the network type of structure being promoted by slow cooling through that range, and the Widmanstätten type by fast cooling. In view of their short granulation zone, hyper-eutectoid steels should be made up of smaller austenitic grains, for like cooling conditions, on reaching their thermal critical range, than hypo-eutectoid steels, and this is known to be so.

If the dendritic segregation which necessarily accompanied the solidification of the steel has persisted, it will be possible by treatment with the Le Chatelier reagent to reveal the dendritic character of that solidification, although the dendrites themselves no longer exist. Copper will be deposited on the ferrite plates of the pearlite present in the axes because of their greater freedom from the segregated element, while it will not be deposited on the ferrite plates of the pearlite in the fillings, owing to their impurity. Copper will not deposit on cementite either in the axes or in the fillings. A dendritic structure is thus revealed.

Steel containing 1.80 per cent carbon should not undergo granulation since it enters its zone of secondary crystallization as soon as it has solidified. Belaiew believes that the separating cementite will then be located along the crystallographic axes resulting in what he calls "structure of large crystals." As the revelation of a dendritic pattern depends solely on persistent dendritic segregation, being independent of the location of the separating constituent, treatment with the Le Chatelier reagent should bring it out by depositing copper on the ferrite plates of the

pearlite present in the axes and not on the ferrite plates of the pearlite of the fillings.

Influence of Heat Treatment on Microstructure

The influence of heat treatment on the microstructure and on the dendritic segregation of steel will now be briefly considered. Let it be stated at the start that while a prolonged heating at a

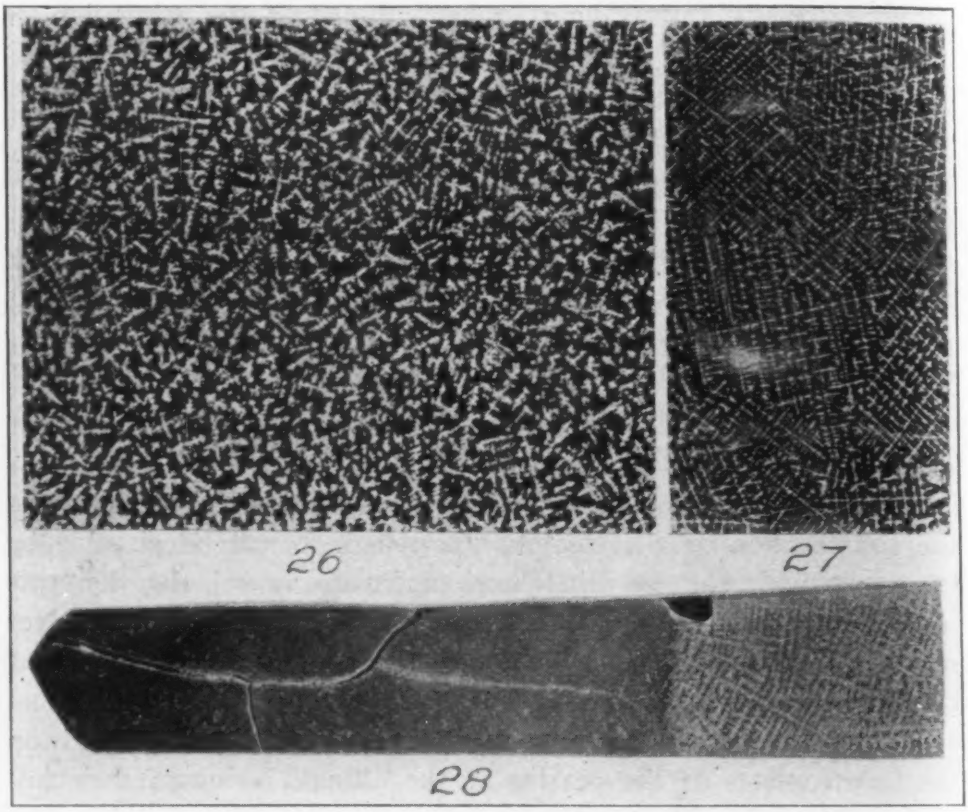

Fig. 26—Dendritic Segregation in Pearlitic Steel Annealed from 1500 degrees Fahr. ×—3. Etched with LeChatelier Reagent. (V. N. Krivobok in author's laboratory); Fig. 27—Dendritic Segregation in Sorbitic Steel. ×—1¼. Fig. 28—Dendritic Segregation in Troostitic Regions of a Quenched Steel. Etched with LeChatelier Reagent. ×—2. (R. F. Smith in author's laboratory.)

high temperature may induce diffusion and, therefore, decrease if not obliterate dendritic segregation, the commercial heat treatments are seldom of such character as to cause much diffusion. It is for this reason that after such treatments, it is generally found that the dendritic structure can still be brought out by suitable treatment. Dendritic segregation still persists. If the heat treatment results in pearlitic steel, the ferrite plates of the pearlite

in the axes as well as any free ferrite which may be present in the axes will be plated with copper while the ferrite in the fillings will not, (Fig. 26). If the heat treatment results in sorbitic steel, copper will be deposited on the minute particles of ferrite present in the sorbite of the axes. (Fig. 27).

Fig. 28 shows strikingly the action of the Le Chatelier reagent in bringing out a dendritic pattern in troostitic areas while it fails to affect the martensitic portion of the same sample. This is further illustrated in Figs. 29 and 30, where the same spot of

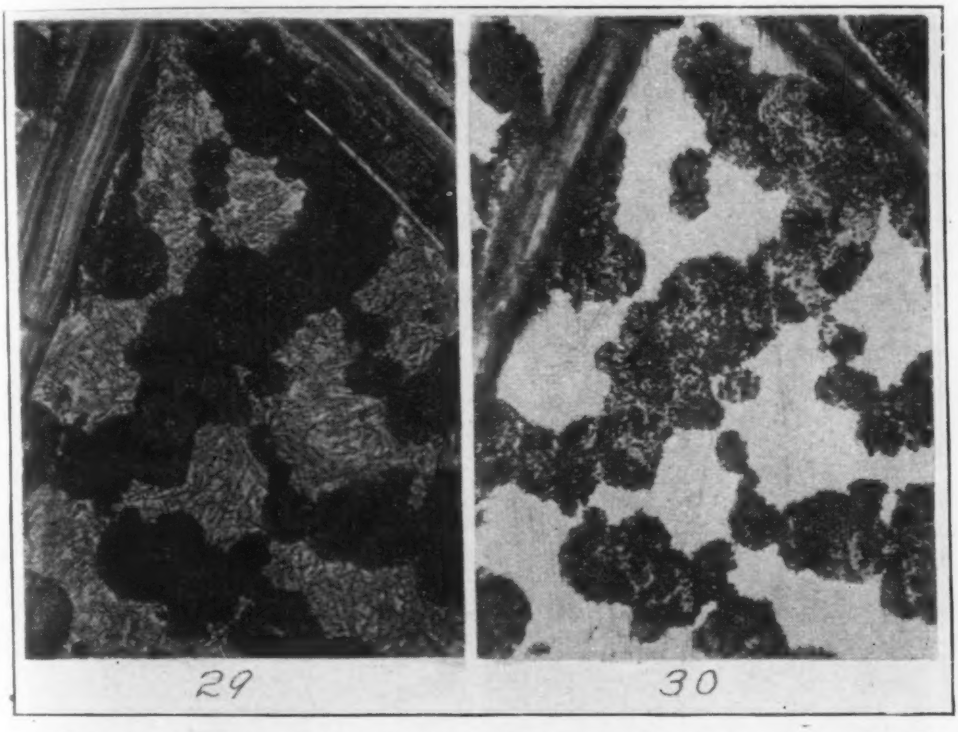

Fig. 29.—Quenched Hypo-eutectoid Steel Etched with Nitric Acid. ×—500. Fig. 30—Same Spot of Specimen as Fig. 29 Etched with LeChatelier Reagent. ×—500. Copper has Deposited on the Ferrite Particles Present in Troostite Imparting a Mottled Appearance to the Constituent, while the Martensitic Matrix Remains White and Brilliant. (R. F. Smith in the author's laboratory.)

a quenched hypo-eutectoid steel casting has been etched with dilute nitric acid and also with the Le Chatelier reagent. Copper has deposited on the ferrite particles present in troostite, imparting a mottled appearance to that constituent, while the martensitic matrix remains white and brilliant.

The fact that a dendritic structure may often be brought out in a steel made troostitic by heat treatment when etched by the

Le Chatelier reagent is, in the author's opinion, an indication that minute particles of ferrite are present in troostite; in other words, that that constituent is of the nature of an aggregate. Steel made martensitic or austensitic by heat treatment does not exhibit a

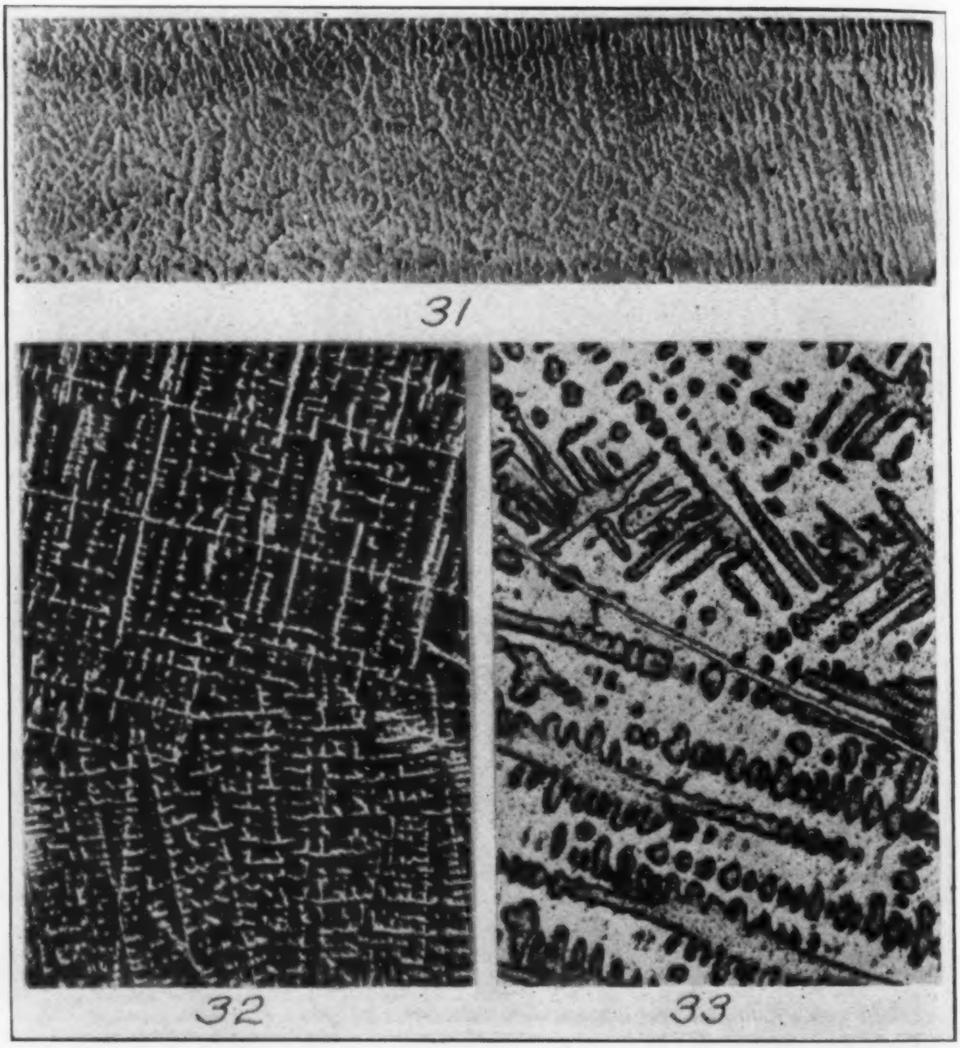

Fig. 31—Dendritic Segregation in Martensitic Steel Etched with Tincture of Iodine. ×—2. Fig. 32—Dendritic Segregation in Austenitic (Manganese) Steel Etched with Tincture of Iodine. ×—22. Fig. 33—Dendritic Segregation in Austenitic (nickel) Steel Etched with Ferric Chloride. ×—60. (Photomicrographs by V. D. Krivobok in the author's laboratory.)

dendritic structure when treated with the Le Chatelier reagent. This is because it does not contain ferrite and it is on ferrite only that copper is deposited. It does not follow that in such steel,

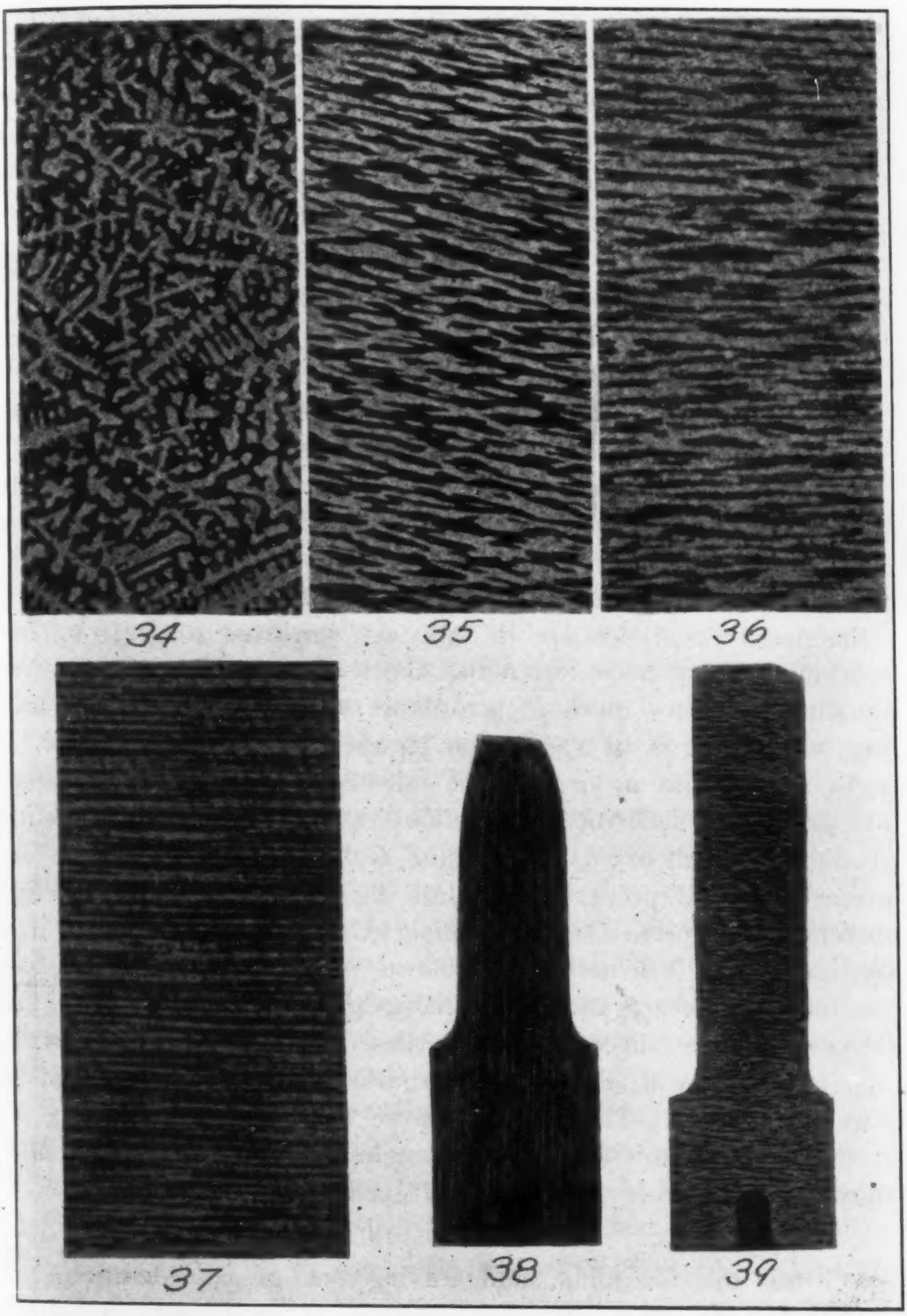

Fig. 34—Dendritic Structure in Cast Steel Ingot; Fig. 35—Same as Fig. 34 after Being Reduced 1/5 its Original Cross-section by Hot Working; Fig. 36—Same as Fig. 34 after being Reduced to 1/30 its Original Cross-section by Hot Working; Fig. 37—Same as Fig. 34 Reduced 1/150 its Original Cross-section by Hot Working; Figs. 38 and 39—Dendritic Segregation in Longitudinal and Transverse Tensile Test Bars. (After Charpy.)

dendritic segregation no longer exists. It merely indicates that the Le Chatelier reagent is now ineffective. Other treatments must be applied. Indeed, the existence of dendritic segregation in martensitic and austensitic steels may be brought out by etching with other reagents, (Figs. 31, 32, 33).

Influence of Work on Dendritic Segregation

If we now turn to the influence of work on dendritic segregation, we naturally find that the portions rich in the segregating elements (the fillings of the dendrites) as well as those poor in these elements, (the axes) are elongated in the direction of the work, imparting to the hot worked steel the well known laminated appearance readily revealed by macro-etching, (Figs. 34-37.) The steel seems to be composed of parallel bands. Some of these bands contain much of the segregating elements while others are quite free from them. The Le Chatelier reagent deposits copper on the latter while the former remain little, if at all, affected. Directional properties are in this way imparted to steel by hot working. The tensile strength, elastic limit and especially the ductility will vary much in accordance with the direction of testing, whether it is in a direction parallel to that of the work, at right angles with it, or in some other direction. In the absence of persistent dendritic segregation such structural orientation should not result from hot working and the metal should not acquire directional properties. Indeed the author is not aware that directional properties can be imparted to chemically pure iron by hot work. Obviously, the more pronounced and persistent the dendritic segregation, the more pronounced the directional properties. The directional properties resulting from hot working, combined with dendritic segregation is further illustrated in Figs. 38 and 39. The test bars were cut respectively in the direction of the work and at right angles. The much greater ductility of the former bar is clearly seen.

Conclusion

From the foregoing, and leaving out of consideration, the chemical composition and the presence of inclusions, it seems reasonable to assume that the physical properties of steel depend (a) upon its microstructure and (b) upon its persistent dendritic segregation. The influence of the microstructure has been ex-

haustively studied, but that of the dendritic segregation has been much neglected; indeed there are many who do not even suspect its existence. This paper is a plea for the study of that influence.

Persistent dendritic segregation is always harmful and should, if possible, be prevented or reduced. There seems, however, but two ways of eliminating it, to wit, by the absence of segregating elements, or by diffusion so complete as to cause the dendrites to become chemically homogeneous. In dealing with the first of these, we at once face a difficulty resulting from our ignorance of the elements responsible for persistent dendritic segregation. If, as Le Chatelier believes, oxygen is that element, we must of necessity always encounter some dendritic segregation since it is not a practical operation to melt our steels in vacuum. We may, however, lessen it by reducing, as much as it lies in our power, the oxidation of our steel. Well made electric steel and crucible steel as well as armco ingot iron should in that respect be superior to the product of other steel furnaces. If on the other hand, following Stead, phosphorus, is the chief cause of persistent dendritic segregation, there seems to be little to be done to prevent it as the steel of good quality at present manufactured is as low in phosphorus as is practical to make it.

In regard to the second means of preventing persistent dendritic segregation, namely by promoting complete diffusion of the segregated elements, it must be admitted that the ordinary heat treatments fail to accomplish this, although they may in some degree diminish segregation. Very slow solidification should help. Very long exposure to high temperature or repeated heating and cooling through the critical range would not be, in the majority of cases, a permissible operation.

Admitting the impossibility of completely preventing persistent dendritic segregation, we should recognize its existence and use all possible means for minimizing its harmful influence. We should endeavor to produce in our finished castings dendrites as small as possible and as free from persistent dendritic segregation as possible by suitably regulating the casting temperature and solidification conditions. We should regulate the cooling through the granulation zone, between the solidus and the ther-

Concluded on Page 83

HIGH-BROW VERSUS LOW-BROW
By Walter M. Mitchell

THERE is a very prevalent idea among many of those engaged in the noble art of heat treating that the only means of becoming proficient in this art is through practical experience, or by practical talks given by shopmen; and further, that no one really knows anything about the subject but the man in front of the furnace. The High-brow, who works in the laboratory, and publishes a technical paper about some obscure atom or molecule which he has caught by the hind legs, cannot, and does not know anything about heat treatment, and if placed between a furnace and a quenching tank at $40 per, would soon loose his job. Perhaps so—and yet perhaps not. The man who gives a practical talk, or writes a practical paper, gives other men, who are working with the same kind of equipment and on the same class of work, information which will be useful to them, but it may not be useful to anyone else. A practical talk on hardening razor-blades by a man in Hoboken will not necessarily benefit some man in Kansas City who wants to temper fishhooks. The practical talk tells us *what* to do, but not *why* to do it, and that is what the heat treater should know.

The High-brow, who makes investigations in the laboratory, studies the changes that take place in the constitution and structure of steel, and so learns what happens to a piece of steel when he hardens it, or when he anneals it, or why it will need normalizing. The technical paper which he writes explains some phase of what the heat treater is trying to do, and the man who knows what he is trying to do; i. e., who understands what changes he must bring about in the structure of the steel in order that it will have the properties that are desired when he gets through with it, is far better equipped for success with any kind of steel than is the man who knows only that if he does certain things at certain times a more or less certain result will follow. The latter method of heat treating is like the method of the man with the famous clock. It always kept splendid time—every time that the hands pointed to two and it struck seven he knew that it was three in the afternoon; but unfortunately this did not help

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him when the hands pointed to five and it struck twelve, as it sometimes did. In that case he always blamed it on the stock room and said they had sent up the wrong kind of steel.

There is a certain steel works, which is probably only one of a dozen like it, and which for obvious reasons must be nameless, where a large portion of the output is heavy forgings of carbon and alloy steel. The carbon forgings are annealed, the alloy steel quenched and tempered—the specifications equivalent to those of the A. S. T. M. for the same class of material. This plant has an excellent microscope, recently purchased. There are two men in the organization who really know something of metallography, and that martensite is not a new explosive, or pearlite a substitute material for 10-cent store jewelry. These men are not directly in control of the heat treating department. During five months association with this works, the writer has never seen either the superintendent of the heat treating department, or his assistant, using the microscope. They appear to regard it as a nice piece of apparatus, but entirely without practical use in heat treatment. The statistics for heat treating various lots of these forgings, a part of the regular output, are as follows:

Annealed 45 per cent Carbon Steel Forgings

	Passed specification	Failed and ordered reannealed	Percentage reanneal to total
1st anneal	64	37	36.5
2nd anneal	17	12	41.0
Heat Treated Alloy Steel Forgings			
1st treatment	83	33	29.0
2nd treatment	20	10	33.3

This shows that there were 130 lots of carbon steel forgings annealed, of which only 81 lots passed specifications; while with the alloy steel forgings, 146 lots were treated, of which only 103 lots passed. In other words this department was treating nearly 50 per cent more steel than it produced, and consequently was costing the company very much more than it should.

Another plant during the early stages of the world war had a large contract for forgings of 3.5 per cent nickel, 2.25 per cent chromium steel, weighing about 1400 pounds each. When work commenced on these forgings reanneals ran between 16 and 18 per cent a week. The management, which was very Highbrow, studied long and carefully to eliminate the cause of this

large percentage of retreatment, with the result that reanneals were eventually reduced to less than 3 per cent, and were maintained at that figure for weeks at a time—even under such a severe test as the microscopic examination of two specimens from each forging. Expensive? Yes—perhaps—but certainly not as expensive in the long run as treating half again as many tons of steel as are produced.

It is not to be supposed that the number of retreatments at the first plant can ever be reduced to the low average established at the second plant, because the forgings at this plant were uniform in size—a condition most favorable to success. But it is believed that a very material reduction in such retreatments would result if proper control were secured through careful microscopic examination of the forgings before and after annealing.

Heat treating deals with the processes and laws of Nature. But many heat treaters do not realize or stop to think that Nature is always right and never misses a trick, and cannot be fooled by any short-cut methods. Successful heat treating is not easy to accomplish, it can only follow when we understand what we are trying to do, and plan operations so that these same laws of Nature will have full opportunity to act. Nothing ever happens by chance, there is always some cause preceding it; but the cause may be, and frequently is, so obscured that we do not recognize it. When a heat treatment goes wrong there is *always* a reason *why*. This reason may not be easy to identify and frequently appears not to exist at all, but nevertheless does exist. Sometimes the cause of failure is under our control, or again it is not, but the most vital preliminary to success is to prevent that combination of circumstances which produced failure if such is possible; or if not, to alter procedure and conditions so that the elements which are not under control are largely eliminated.

The function of the High-brow, through careful investigations and researches, is to discover the natural laws that control the operations of heat treatment and the constitutional changes that necessarily must be produced in steel, so that we know and understand *why* a certain procedure must be followed. The Low-brow, on the other hand, with many years of practical experience gained by the observation of facts and conditions that cannot conveniently be reduced to mathematical formulae, tells us *how*

to do it. In this way both have their part to play and we cannot dispense with, or depreciate, either one.

Many years ago the hardening of steel, or what we now call "heat treatment," was a mysterious and almost sacred art, to be trasmitted only from father to son, or to some favored apprentice, rigidly bound to secrecy. All sorts of magical formulae and concoctions were used and regarded as essential in the prevention of failure—the famous red-haired boy and the fat negro slave, for instance. But the High-brow, through intimacy with solid solutions, allotropic transformations, eutectics, etc., has dispersed this fog of medievalism so that heat treatment is no longer a subject of dark mystery and incantation. Many of the High-brow investigations appear to be without practical value, but no one can predict what ultimate benefit may result. A few years ago tungsten was regarded as a laboratory curiosity, its discovery a scientific stunt; yet this same laboratory curiosity has revolutionized machine shop practice throughout the world, and in replacing the inefficient carbon filament of the incandescent lamp has many times repaid the cost of the seemingly impractical investigations. Vanadium, one of the rarer metals, was for a long time of interest to astronomers only, as a prominent constituent of sun-spots, shown by the spectroscope; while today it is a vitally important ingredient of high grade steels. Many similar illustrations might be given, but they would all point to the same truth. They are a direct result of the High-brow laboratory investigations which are sometimes so freely criticized and disparaged.

There is a vast field of metallurgy yet to be discovered, the knowledge of which must ultimately be of greatest usefulness. So far we have barely "etched" the surface. Most of the explorations in this unknown land will be made by the High-brow investigator working in the laboratory on things which to the man in the shop—and alas, too often to the executive—seem to be of no practical use. Let us by all means encourage such investigations that we may ultimately profit by the results obtained. The technical papers and discussions are really prepared for our enlightenment and education, if we can but see it that way. And education is the basis upon which the American Society for Steel Treating was founded—but there are many of us who do not know how badly we need it.

FORGING AND HEAT TREATING LARGE SECTIONS

By W. R. Klinkicht

Abstract

This paper describes the routine operations which are used in the forging and heat treating large section, as practiced in a modern heavy forging plant, equipped with suitable cranes, manipulating devices and heating equipment. Figures illustrating the operations of the annealing, forging and subsequent heat treating are included.

Introduction

IN VIEW of the wonderful strides made in the past few years in methods and equipment for forging and heat treating, it is interesting to pause for a moment and consider how our ancestors handled their problems in the working of iron and steel, which we know is one of the oldest of arts. We find many references to the art in the Bible where Tubal Cain is referred to as an "instructor of every artificer in brass and iron."

Very little is known of the early smiths, or their methods, however, the illustration Fig. 1 gives as reliable an idea as can be found. A fire was built in a depressed place in the ground, a forced draft being given to the flame by an attendant on either side who worked bellows by standing on them, alternately throwing their weight from one foot to the other and pulling up the bellows with ropes as the weight was shifted, thus permitting the instruments to be emptied and filled alternately. It is interesting to note that the method of forcing a fire by means of bellows was used probably 4,000 years ago.

There seems to have been very little improvement made in the working of iron and steel for many centuries, until the stack furnace and then the Catalan forge and other advances took place, but it was not until the sixteenth century that any attempt was made to apply mechanical instruments in the forging operation. We are told that about the year 1550 the trip hammer, operated by means of a waterwheel, constituted the first attempt at mechanical forging equipment.

A Swedish application of the waterwheel method is shown in

A paper presented before the Cincinnati chapter of the Society. The author, W. R. Klinkicht is connected with the Pollak Steel Co., Cincinnati, Ohio.

Fig. 2 wherein three hammers are shown in operation in addition to the bellows arrangement for smelting and forging. If we are to judge from the illustration, this smith was a busy man, there being bars under all three hammers, in addition to the one he is holding in the heating furnace.

As the demand for wrought iron forgings increased it became necessary to obtain a force of impact greater than could be

Fig. 1.—An Old Sketch Showing Early Smiths at Work Using Primitive Forced Draft Fires.

supplied by human muscles or the methods then in use, so the idea was conceived of attaching a heavy slab of iron to a rope, then lifting it in vertical guides with a gang of men and dropping it from any desired height within the capacity of the machine. This contrivance was called the Hercules and was a fairly efficient tool for that period.

The eighteenth century witnessed the introduction of the lift and tilt or helve hammer, operated first by water-wheels and later by steam. A waterwheel tail hammer of this period is reputed to be in operation today in Sheffield, England. When we consider the class of work turned out with this equipment, we may well marvel at the handicraft of these artisans.

James Watt appears to have been the originator of the first steam hammer and it was patented by him in 1784. However, no steam hammers appear to have been made under his patent and in 1839 James Nasmyth of the Bridgewater Foundry, near Manchester, England, designed and patented a steam drop hammer. This hammer was designed because of an appeal to Mr. Nasmyth, by a Mr. Humphries of the Great Western company, who wished a large paddle shaft forged for a new steamship then under construction. After making a survey of the forge shops in the country it was found that none were able to undertake the forging of

this shaft because of the lack of proper equipment, so the construction of the first steam drop hammer was begun, Fig. 3. The method of the propulsion of the boat was later changed to the screw propeller type so the shaft was not needed and the

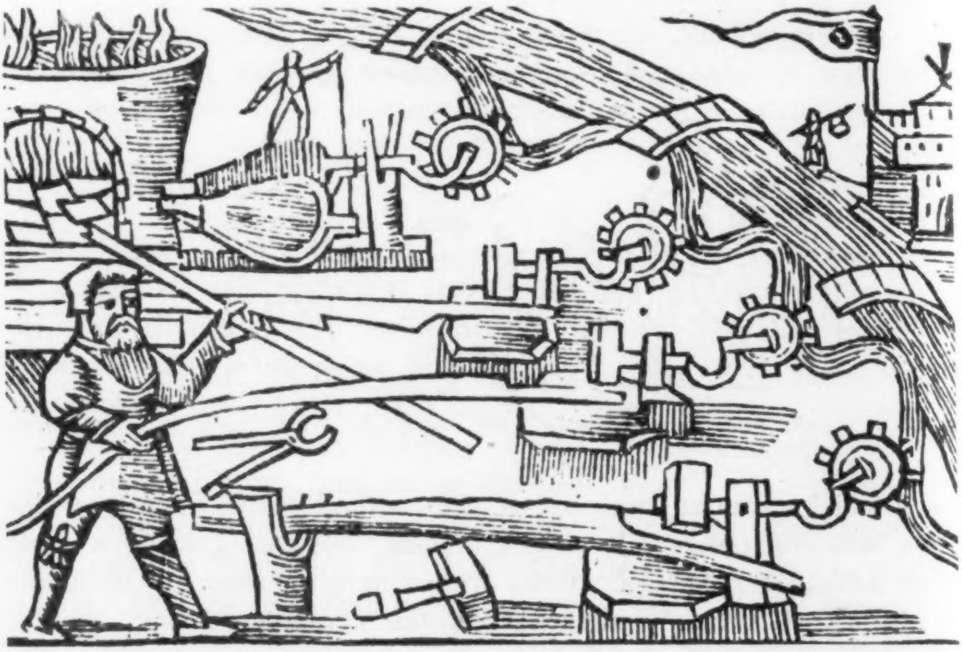

Fig. 2.—A Swedish Application of the Waterwheel for Driving Hammers.

hammer was not completed until four years later. From that time on rapid strides have been made in hammer development and with this development came the hydraulic and steam press.

Pressed Forgings

Forgings made under a press are unquestionably of superior quality due to the deeper and more uniform penetration characteristic of press performance. This point is clearly emphasized in the convexed ends of pressed forgings, and borne out by physical and microscopic tests.

Forgings pressed directly from ingots have shown better physical properties than those forged from blooms because of the more accurate control of temperature and the superiority of pressing over rolling. But, before forging an ingot it is necessary that important points be considered. Most forgings are ordered to specifications calling for certain chemical composition and physical characteristics. The chemical composition having been de-

termined by analyzing drillings taken from various points on the ingot, the weight of the forging as compared with the ingot weight is next to be considered. An allowance of about thirty percent of the total weight of the ingot must be made for

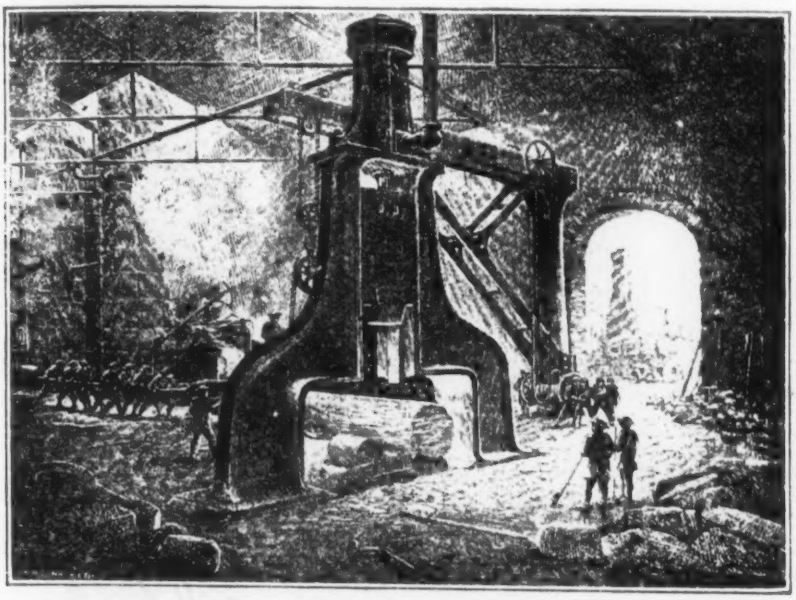

Fig. 3.—First Steam Drop Hammer.
(From Autobiography of James Nasmyth)

discard and the area sufficiently large to permit of a reduction of about four to one. The ratio of reduction is usually greater.

Heating

The heating of ingots for forging is an operation requiring great care. Too rapid heating will cause a rapid expansion of the outside which will cause it to draw away from the interior, resulting in cracks and cavities and for this reason they must be carefully preheated. At the same time a slightly reducing atmosphere must be maintained to prevent excessive decarburization of the surface during the many hours required to thoroughly heat the steel. It has been truthfully said that the real heat treatment of steel begins with the heating for forging and the factors time, temperature and area are as applicable to the forging as well as the heat treating operation. The need of thoroughly trained heaters, properly supervised, is readily apparent.

Time Required for Heating

To accurately determine the actual time required to heat large ingots, tests were made with full size sections by drilling a hole midway into the ingot, inserting a thermocouple carefully wrapped with asbestos and packed around the outside to prevent entrance

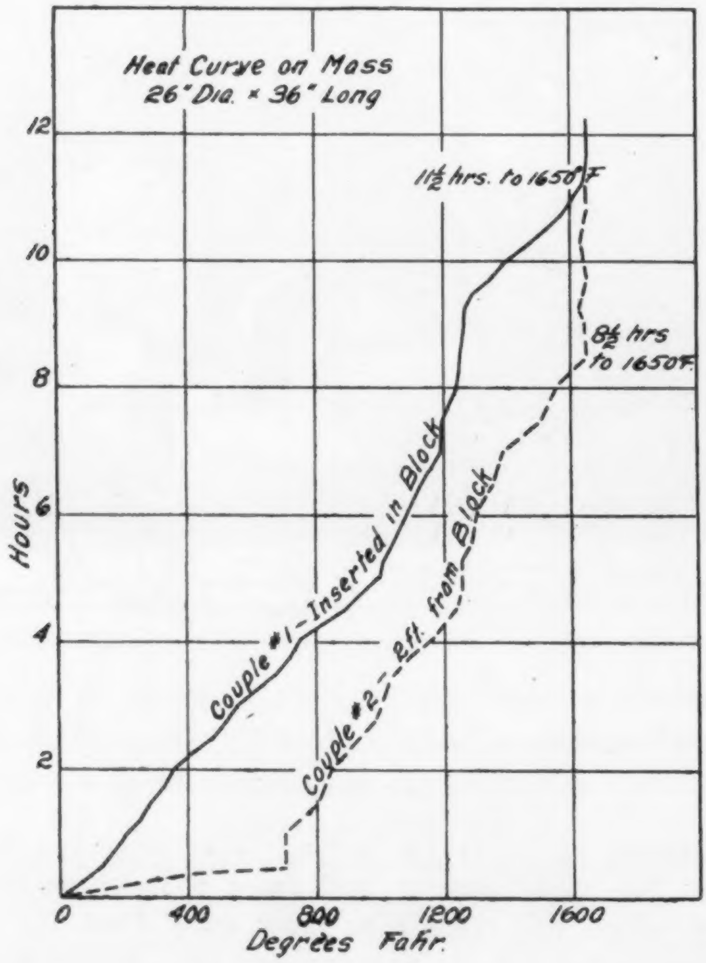

Fig. 4.—Curves Plotted from Results Obtained in Heating a Section 26 Inches in Diameter and Bears out the Generally Approved Statement that One Hour Heating for each Inch of Section is Satisfactory.

of heat. Another couple was then placed in the furnace about two feet away from the steel and the temperatures periodically checked and recorded. The curves in Fig. 4 were plotted from the results obtained in heating a section 26 inches in diameter and bears out the generally approved rule, that about one hour

heating for each inch of cross section is satisfactory. The critical range of the steel is also clearly shown in this chart.

Pressing

After the ingot has been thoroughly heated at the proper

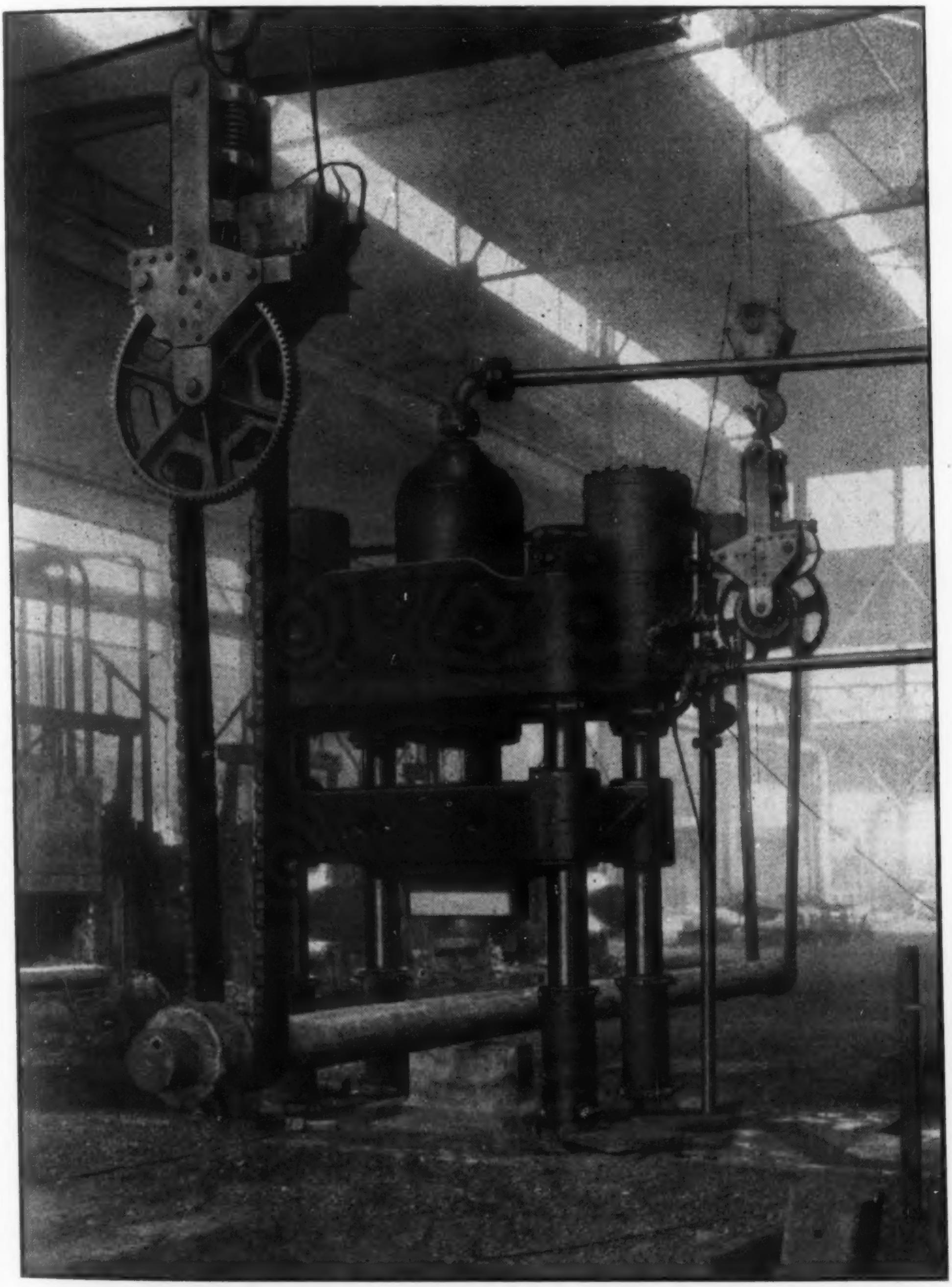

Fig. 5.—A 1000-ton Press Forging a Shaft

temperature, it is removed from the furnace by an electric crane equipped with a motor-driven endless chain belt and placed under the press (Fig. 5, 1,000 tons capacity) for the breaking down operation, which usually begins in the center. The forging operation is directed by the pressman who stands in a prominent position where his signals can be readily seen by the press operator and crane men who must work together. The ingot is worked down in the center first so that subsequent reheatings,

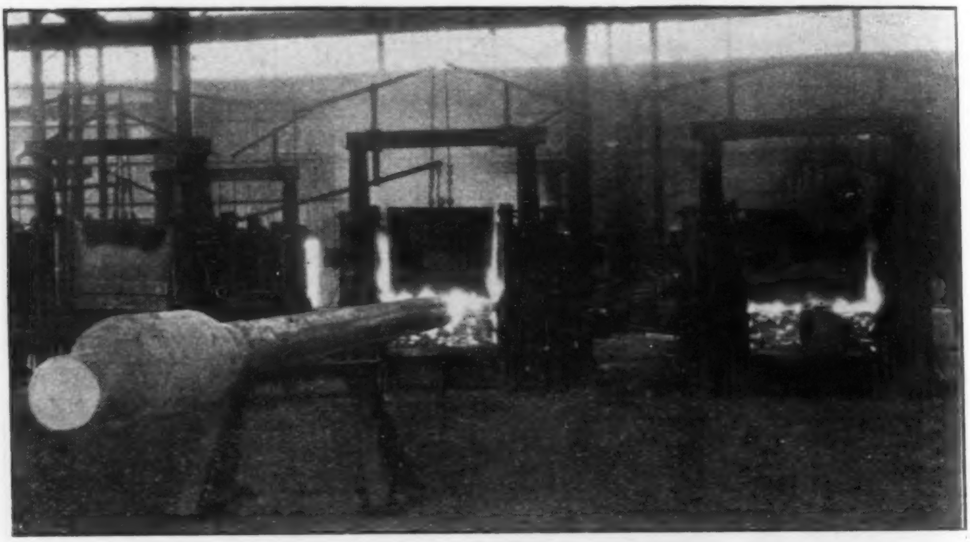

Fig. 6.—Heating Steel for Forging Under the Press.

will be toward the ends of the ingot making it easier to handle after the shaft has been worked out to a considerable length. This working proceeds toward the bottom end, the top end being left until the last as the greatest portion of the discard will come from this end. During the forging operation scale is constantly blown off of the forging and the dies kept clean so that none of this scale is pressed into the forging.

After the bottom end of the ingot has been forged to size, the opposite end is heated and that portion near the center forged out to complete the shaft, the top end being merely roughed down to facilitate handling, as a great portion of this will be discard. In the heating (Fig. 6) of the steel for forging under the press, six furnaces are required to insure operation on a productive basis.

The temperature at which the forging has been finished has

just as important a bearing on the final structure of the steel as the maximum temperature to which it has been heated and it is always the aim of the forgeman to finish the forging as near the upper critical range as possible. The success of the final heat treating depends largely upon the structure of the steel after the forging operation.

On completing the forging it is laid down on a cinder bed where a natural uniform cooling takes place. Sufficient discard to insure sound steel is then made and the forging inspected for dimensions and surface defects, which are properly chipped out before any further work is done on it.

Annealing

The annealing of large shafts calls for properly designed furnaces capable of maintaining a uniform temperature along the entire length, with necessary equipment for handling. The annealing furnaces shown in Fig. 8, are 40 feet long and 54 inches wide, equipped with 11 oil burners, staggered to permit uniform heating throughout. They are also completely equipped with pyrometric control, there being nine thermocouples on each furnace which are connected to a wall indicator for the heater's observation. In addition temperatures are recorded on a recording instrument for future reference, and check.

However, even a pyrometer has its limitations and while it gives an indication of a uniformly heated furnace it does not guarantee that the material in the furnace is heated uniformly throughout, especially if this material be of large cross-section. Here, again, as in the heating for forging, the human element enters into consideration as it is not so much the equipment itself as it is the handling of it, that determines the success of the operation. As an additional check, periodic observations are made through small peep holes in the door of the furnace. The accuracy of these observations depend upon the skill and experience of the operator. The hours for heating are computed on the basis of one hour of heating for each inch of cross-section, care being observed to reduce the saturation above the critical temperature to the shortest time possible and thoroughly heat the steel, as prolonged heating above the critical range will undoubtedly coarsen the grain size.

Quenching and Tempering

Should a forging be ordered to a quenching and tempering specification the routing may be somewhat different. Quite a number of specifications require all forgings above 7 inches in diameter to be hollow bored, and where such is the case the boring operation always precedes the heat treatment. Hollow

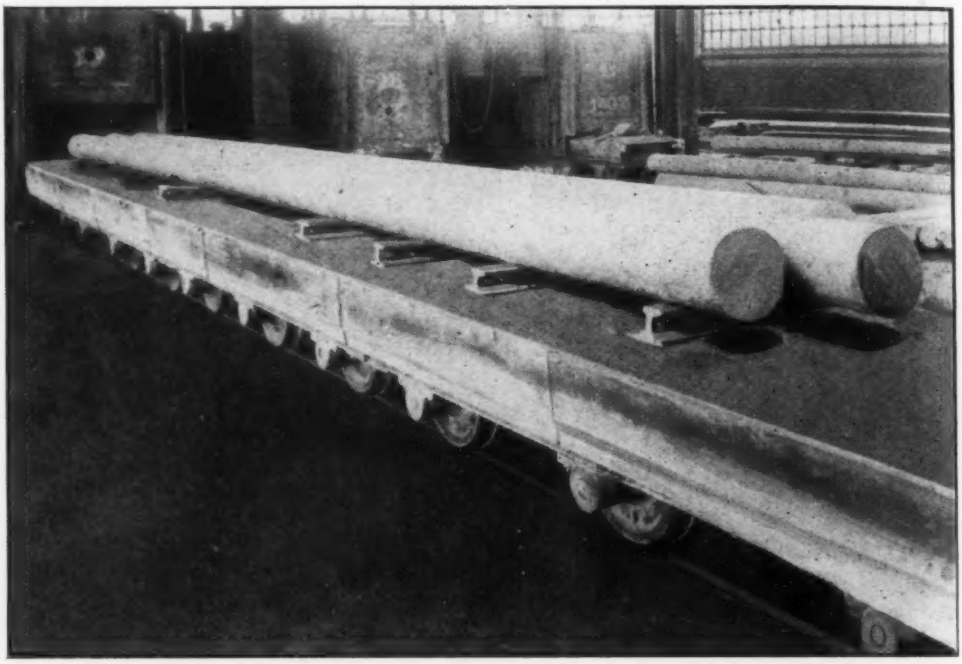

Fig. 8.—Annealing Furnace 40 Feet Long and 54 Inches Wide, Equipped with 11 Oil Burners.

boring (Fig. 9) takes practically nothing away from the strength of the forging, but reduces weight and permits of more uniform cooling in the quenching bath, thereby reducing warpage and increasing the homogeneity of the structure of the steel. At the same time it removes material from the center where defective material is most likely to exist and where it is least subject to the beneficial effects of heat treatment. Examination of the bore has many times lead to the discovery of a defect which would have otherwise remained undetected.

When a forging is ready for the heat treating operation it is placed in a cast steel holder and loaded into a vertical furnace as shown in Fig. 10. The furnace shown is 40 feet deep

and 6 feet in diameter, fired with 18 bull type burners so arranged that the flames swirl around the forging without impinging directly upon it. These burners are accessible from an iron stairway extending to the bottom of the furnace.

Heating for a quench is probably the most important operation in the treating of steel and especially so in respect to large forgings. The same dangers that attend the quenching of a

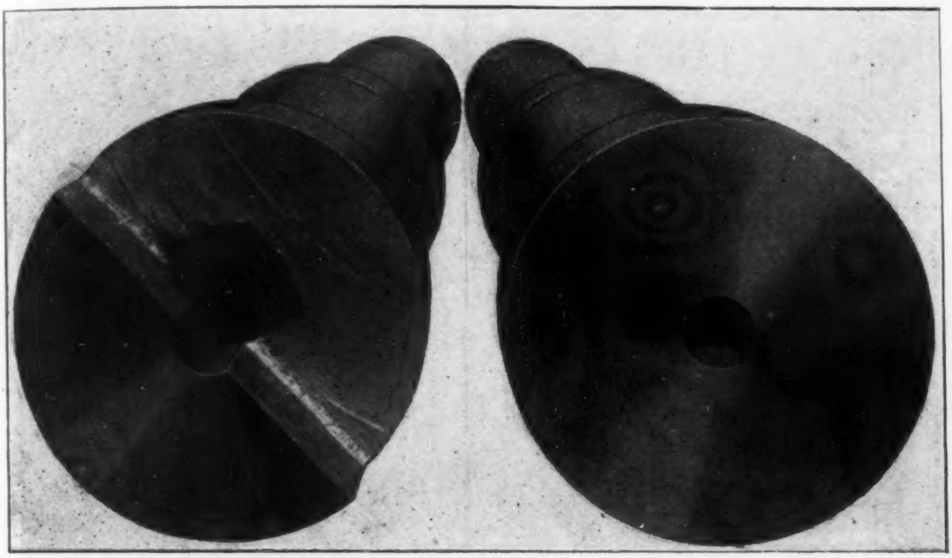

Fig. 9.—Hollow Boring for the Purpose of Removing Defective Centers of Forgings. The Forging on the Left Shows a Defect.

nonuniformly heated tool are in evidence, only highly magnified. We are told that a fairly large section, during the quenching operation, is subjected to tension around the outside, compression midway and tension around the central portion, and unless the steel be sound and uniformly heated, rupture is likely to result.

After the forging has been given the prescribed treatment it is removed from the furnace by a high-speed crane and lowered into the quenching tank immediately adjoining. A soluble oil is used as a quenching medium, it having been found to give the best results after many experiments. With this oil a fairly high elastic limit is possible without the attendant danger of water quenching. The ordinary quenching oils generally used in the heat treatment of smaller material failed to give the desired results due to its lower heat conductivity. Forgings are never per-

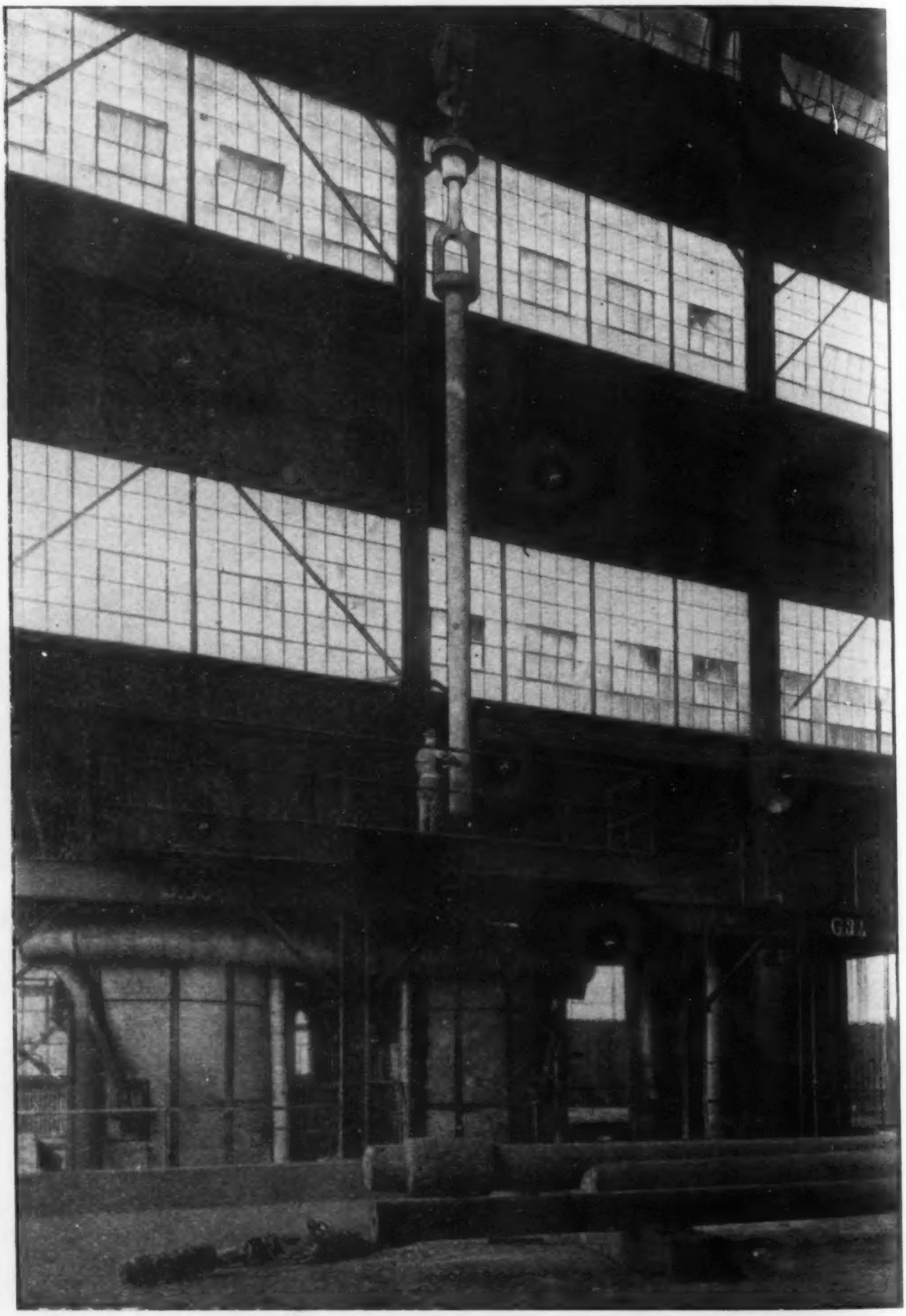

Fig. 10.—Vertical Heat Treating Furnace, Oil-Fired Into Which Forgings are Loaded As Shown.

mitted to become cold in the quenching bath, but are removed at between 300 and 400 degrees Fahr.

To keep a bath at a uniform temperature while several tons of red hot steel are immersed in it is a problem of considerable magnitude. To properly care for this a reservoir capable of holding 150,000 gallons of water was built and a system of pipes arranged so that the oil when pumped from the quenching tank circulates through the pipes and then 200 feet away to a reserve tank whence it falls by gravity into the quenching tank again. After quenching forgings are immediately drawn at a temperature necessary to meet physical properties specified, which will at the same time remove all quenching strains.

Tests

Tests are now taken from the end of the forging by means of a hollow drill, midway between the center and the outside and in the direction in which the forging is drawn out. In plain carbon steel of .40-.50 per cent carbon the 'quenched and tempered' specifications will usually require a standard 2″ test specimen to have a tensile strength of not less than 85,000 pounds per square inch; elastic limit 50,000 pounds per square inch minimum; elongation in 2 inches of 22 per cent and a reduction of area between 40 to 45 per cent. In addition, a section ½″ square must bend cold around a 1″ mandrel to 180° without signs of failure. Annealed forgings are usually required to meet 80,000 pounds per square inch tensile strength and 40,000 pounds per square inch elastic limit, 20 per cent elongation in 2 inches and 32 per cent reduction in area. All valves minimum.

After testing for physical properties, all heat treated forgings are given a proof test which consists of dropping a ton weight on the forging, which is rigidly supported on both ends, from a height governed by its diameter, when it is turned ninety degrees and struck again. This will generally weed out any unsound forging.

Microscopic examination is rapidly gaining favor with users of heavy forgings and where this clause is included in the specification, government standards prevail.

DETERIORATION OF STEEL AND WROUGHT IRON TUBES IN HOT GASEOUS AMMONIA*

By J. S. Vanick

Abstract

This paper describes the failure in service of wrought iron and steel tubes employed in an apparatus used for the decomposition of ammonia. The prolonged exposure of the metal to a current of hot gaseous, ammonia produces a localized disintegration, the position of which is determined by the temperature and ammonia concentration.

The progress of the deterioration, with temperature, is similar for both types of material. Details of the macroscopic and microscopic features of the deterioration of the metal, are mentioned in view of their importance in connection with the study of "nitrogenized" steels.

The relations between temperature and the joint reactions representing the decomposition of ammonia and the nitrogenization of iron are briefly sketched to illustrate the general character of the deterioration of steel in heated ammonia.

I. Introduction

Most investigations concerned with the influence of ammonia on iron or steel have dealt with the effect produced upon the properties through the nitrogenization of the metal by means of short exposures to ammonia, at high temperatures. Usually an exposure of a few hours, or at most 24 hours, in a current of ammonia at a temperature of about 650 degrees Cent., is sufficient to produce the desired degree of nitrogenization. Within this period of time an appreciable change in the mechanical properties occurs which is sufficient to destroy the usefulness of the metal for many structural purposes. The changes in mechanical properties are usually accompanied by differences in composition

*Published by permission of the Director, Fixed Nitrogen Research laboratory, Department of Agriculture, Washington, D. C.

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or structure which are readily disclosed by appropriate methods of test.

Where properties such as strength, ductility and hardness are unimportant, steel may be exposed to hot ammonia for relatively long periods of time before destruction by disintegration occurs. At the Fixed Nitrogen Research laboratory, ordinary steel and wrought iron tubes of the following typical analysis, have been used for periods varying from six to nine months before failure by deterioration or "burning through" occurred. A number of tubes, some of which had failed in

	Carbon per cent	Manganese per cent	Phosphorus per cent	Sulphur per cent	Silicon per cent
Steel	0.11	0.38	0.068	0.035	0.008
Wrought iron	0.08	0.37	0.117	0.067	0.006

service, have been carefully examined. The deterioration is quite similar in each case. In view of this, the substance for this paper was abstracted from several reports describing the failures in service of tubes used in the ammonia decomposer, or cracker. The decomposer is an auxiliary unit which is used to "crack" ammonia into its constituent gases, nitrogen and hydrogen.

It consists* (as shown in Fig. 9) of two to four concentric tubes of standard dimensions, fitted one within another with a space of one inch or more between walls. A heating coil is wound about or suspended within an inner tube, to provide the heat necessary for the ammonia decomposition. The intertube spaces with the exception of the one occupied by the heating coil, are packed with steel wool to distribute the heat and facilitate the ammonia decomposition. A thick packing of heat insulating material encases the entire apparatus.

Ammonia gas at a pressure slightly above atmospheric (2 m.m. Hg), is conducted through the intertube spaces and "cracked" into nitrogen and hydrogen. Upon entering, the ammonia gradually absorbs heat; a superheated condition with respect to the reaction NH_3 going over to N_2+H_2 is developed and the decomposition of the gas rapidly takes place. The ammonia content at the exhaust end, is well under 0.5 per cent.

The actual decomposition of ammonia begins with the

*See Larson, Newton, Hawkins, Tour, *Chemical and Metallurgical Engineering*, March 15 and 29, 1922, for additional description.

entrance of the gas into the decomposer. The rate of decomposition at temperatures below 300 degrees Cent. (572 degrees Fahr.) is very slow but in the temperature range from 450 to 650 degrees Cent. (842 to 1202 degrees Fahr.) the reaction rate is appreciably accelerated. This rapid rate is reached in the second tube of the type of "cracker" shown in Fig. 9, and the portion of the tube within which it occurs is referred to as the "cracking zone." Failure by "burning through" occurs in a narrow band or collar near the high temperature portion of this zone.

Temperatures along the outer wall of the "crackers" were measured because of the inaccessability to the interior of the earlier types. In each case, a curve similar to that reproduced in Fig. 9, was obtained. Obviously a slightly higher temperature prevailed in the interior. The position, with reference to temperature of the specimens which were cut from the second tube, are indicated in the diagram. The position of maximum deterioration and failure, corresponded to the position of specimen 3, of the diagram.

II. Service Failures of Wrought Iron and Steel Tubes

It is impossible from the data available from service tests, in which conditions are not strictly comparable, to draw specific conclusions as to the actual value of wrought iron versus steel tubes. Fundamentally, the deterioration from the standpoint of chemical attack, is similar. Physical effects produced during the disintegration, differ characteristically for each type of material. The coarse features of the disintegration are sufficiently accentuated in the wrought iron tube, to distinguish it from the steel, in a preliminary inspection.

An inspection of the tubes after their removal from service, invariably revealed a progressive deterioration from the cooler toward the hotter portions. Blistering, surface-cracking, and fissuring increased with the temperature. The size, number and depth of blisters, was decidedly greater, in the wrought iron tube. Fig. 1, shows a series of specimens representing consecutive sections of an exposed wrought iron tube. The temperature range within which the blisters occur, extends from 400 degrees Cent. (752 degrees Fahr.) upward. The appearance of the surface immediately suggests blister steel.

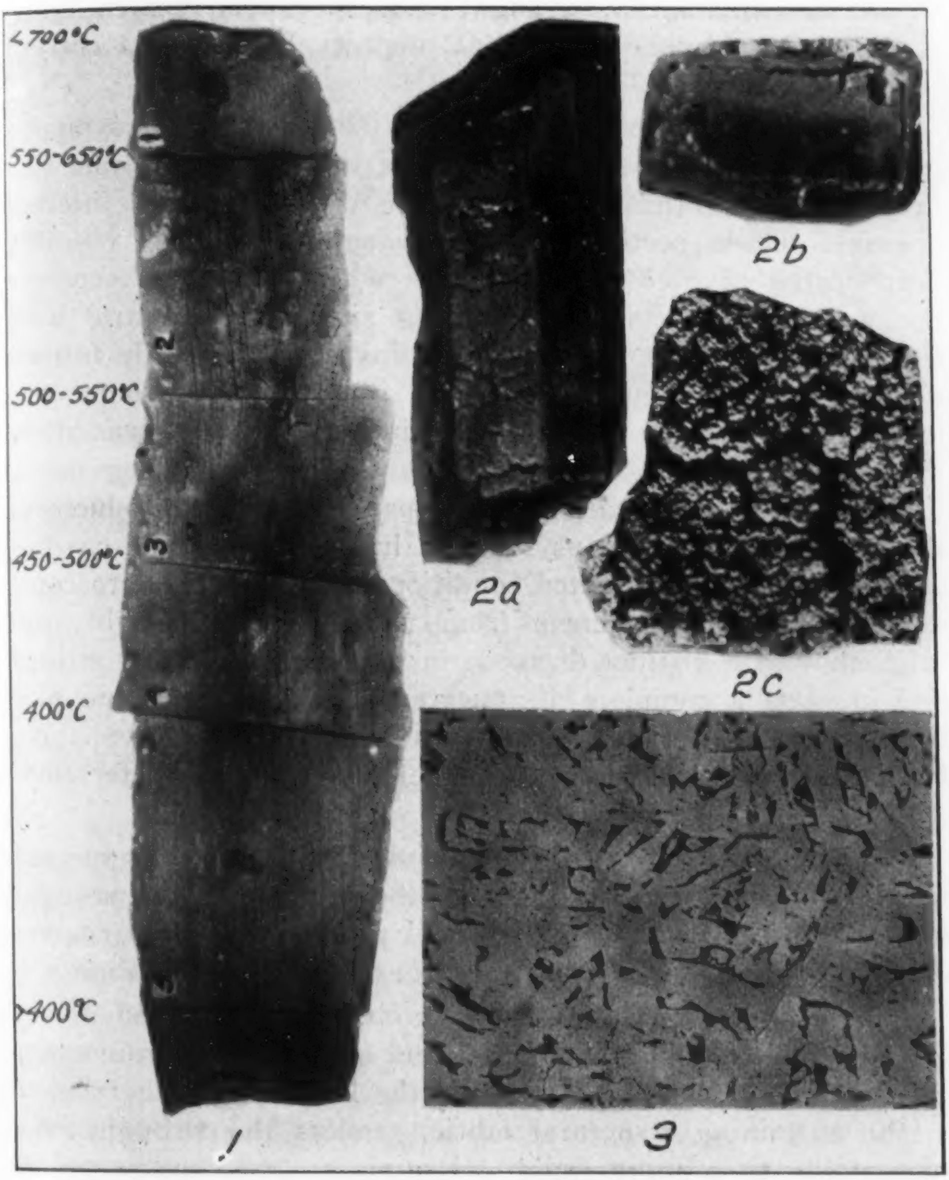


Fig. 1—Sections from Corroded Surface of Wrought Iron Tube. × 1/3. Figs. 2—a, b and c—Severely Corroded "Collar" in Zone III. ×1 2/3. Fig. 2a—Cross Section of Tube in Zone III; Fig. 2b—Cross Section of Tube at Junction of Zones III and IV; Fig. 2c—Surface of Tube in Zone III. Specimens 2a and 2b are Encased in a Plating of Copper. Fig. 3—Microstructure—Unaffected in Low Temperature, High Ammonia, Zone. ×100. Figs. 2 to 8 Represent a Single Steel Tube.

The occurrence of the blisters, is attributed to the action of a reducing gas (in this case, hydrogen), upon the enveloped oxide, silicate or sulphide particles. That a prolonged exposure to the hot gas is necessary, is demonstrated in the failure

to develop blisters in wrought iron specimens heated for 7 days, at 650 degrees Cent. (1202 degrees Fahr.), in a current of ammonia.

The pressures exerted by the expansion of the entrapped gases formed by the decomposition of the inclusions, were sufficient to break through the surface crust or widen internal cavities. Cross sections of the wrought iron tube, revealed deep seated cavities or laminations which tended to separate the wall into sheets along parting surfaces concentric with the curvature of the tube. The laminations apparently formed along the broad, continuous sheets into which the inclusions in the tube had been worked. The infiltration of the gas along the contact between the inclusion and the surrounding metal, followed by the formation and expansion of the products of the gas—versus inclusion's reaction had developed the cavities and produced the exfoliated condition in the wall. Microscopic examinations of specimens from the exposed wrought iron tube, showed a distinct decrease in the number of slag strings and in parts a complete disappearance of them. Minute particles, embedded within the grains remained unaffected. No trace of former inclusions could be found in the blister cavities.

In the steel tubes, a thin sprinkling of blisters appeared which lacked the size and depth of those developed in wrought iron. The deterioration of the steel tubes, free of the coarser defects progressed in a more uniform and thorough manner.

The above description sums up the principal differences between the deterioration of the steel and wrought iron tubes. The preponderance of inclusions in the latter and their relation to the sustaining structural fabric, renders the wrought iron susceptable to a more rapid destruction.

III. Macroscopic Features of the Deterioration

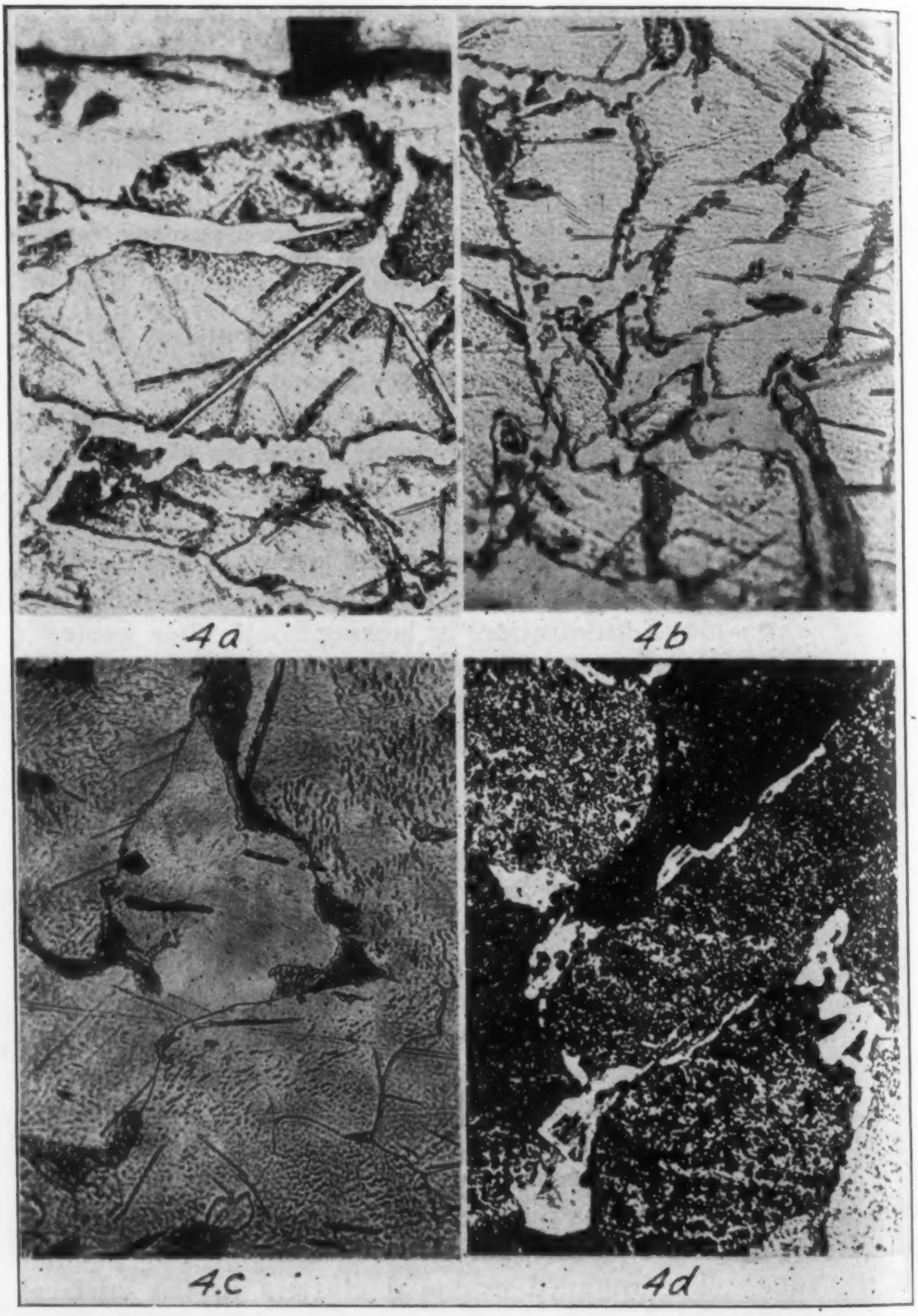
For a more detailed inspection, specimens were cut from positions along the tubes, selected to represent the different temperature ranges. The positions of the specimens within the various zones, are marked in Fig. 9. Each zone presents a change in the condition of the tube which is related to the temperature and ammonia concentration to which the surface

had been subjected. The specimens, with respect to this relation were estimated to lie:

Zone	Temperature Degrees Cent.	Ammonia Concentration
I	below 400	Concentrated—ammonia, zone.
II	400-500	Ammonia concentration, over 80 per cent.
III	500-700	"Cracking" zone, ammonia concentration from 80 to 5 per cent.
IV	700-750	Ammonia concentration 5 to 0.5 per cent.
V	750-680	Ammonia concentration less than 0.5 per cent.

The true relation between each zone and the ammonia concentration of the gas with which it was in contact, has not been specifically determined. It is quite generally assumed that most of the ammonia is decomposed in the severely corroded zone. The decomposition would occur in the position of zone III. Proof of this in the form of actual determinations of the ammonia concentration is lacking, but other evidence which will be mentioned later, tends to support the assumption made.

At the lower temperatures, corresponding to zone I, the tubes appeared to be unaffected by the action of ammonia. Above 450 degrees Cent. (842 degrees Fahr.), in zone II, the surface was covered with a slaty coating which, as subsequent analysis indicated, was the iron nitride. The coating was very brittle and flaked readily, when struck. The coated surface showed no surface cracks. In passing to the higher temperature portion of this zone, the coating gradually disappeared. Surface cracks appeared and prevailed over the remainder of the wall; the crack meshes becoming smaller with the increasing temperature. The cracking was accompanied by a surface roughening which reached a maximum in zone III, and gradually disappeared in zone IV. The appearance of the surface in zone III is pictured in Fig. 2. Fig. 2c shows the alligator cracks and deep fissures which traverse this portion of the tube. The rounded or nodal clusters in the surface, suggest a partial fusion and flow of the surface projections under the action of the heat and the decomposing ammonia. The localization of the attack on the metal is revealed in a comparison of Figs. 2a and 2b, which represent transverse sections



Figs. 4—a, b, c and d—Structures Approaching the "Cracking" Zone. Same Tube as Represented in Figs. 2 and 3. Fig. 4a—Massive Nitride Along Surface, Intergranular Channels and Intercleavage Filling. ×500. Fig. 4b—Same as Fig. 4a, further from Surface. ×500. Fig. 4c—Structure in the Interior Showing Nitride Plates and Patches. ×500. Fig. 4d—Massive Nitride after 30-minute Etching in Sodium Picrate. Ferrite Grains Severely Pitted by the Etching. ×500.

cut within 3 to 4 inches of one another from the severely corroded zone. The fissured, porous, layer which prevails in this portion of zone III, terminates abruptly in the compact appearing backing of the wall. The distinct difference in the width of the fissures and the depth of penetration of the porous layers of specimens 2a and 2b, illustrates the sharply defined localization of the attack. In zone V, the surface roughening does not appear, and the surface, except for microscopic cracks, appears to be unaffected.

IV. Microscopic Features of the Deterioration

A microscopic examination of specimens representing the different zones, to some extent reveals the character of the deterioration. To simplify the description, a single steel tube has been used for the following illustrations.

The results of the microscopic examination may be summarized in a paragraph. Microstructures of the tube sections showed that ammonia is feebly active below 400 degrees Cent. (752 degrees Fahr.). Above 400 degrees Cent. destruction begins and increases with a rise in temperature, reaching a maximum in the 550 to 700 degrees Cent. (1022 to 1292 degrees Fahr.) range. Above this temperature and in the temperature drop that follows, (Fig. 9), the distinct change in the degree of destruction and the character of the disintegration respectively marks a decrease in the intensity of the reaction ammonia going over to nitrogen plus hydrogen and a change in the reaction from decomposition to equilibrium or possibly, to synthesis in the cooler exhaust.

The structure prevailing in the lower temperature, high ammonia zone, is illustrated in Fig. 3. Compounds of nitrogen are not detectable. With the exception of a slight roughening along the exposed edge, the structure is unaltered.

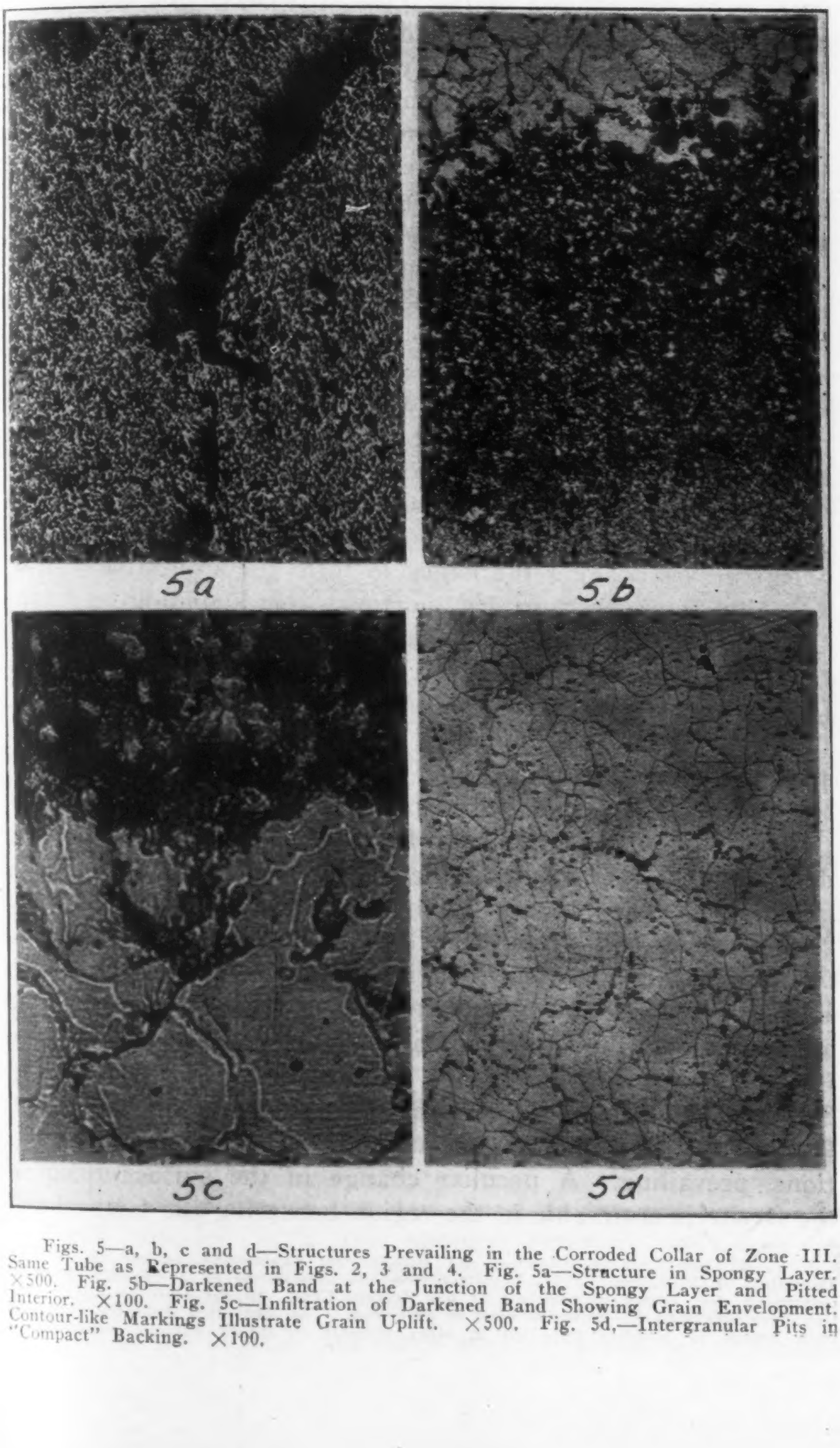
Figs. 4, a, b, c, and d, illustrate the condition of the structure in zone II. As previously mentioned, the surface was covered with a slaty film, which analysis indicated was the nitride of iron Fe_2N. Shavings planed from the coated surface though contaminated heavily by the underlying metal, yielded over 4.25 per cent nitrogen* upon analysis. Figs. 5, a and b, show the junction with the underlying ferrite grains,

*Credit is due L. Smith, associate chemist, for this work.

of the highly reflecting "white layer" of iron nitride. The nitride in this massive form is not limited to the surface but a penetration along the grain boundaries which envelopes the sub-surface grains is evident. The intergranular filling decreases in thickness as the interior of the wall is approached until the massive form is replaced by the plate and patch type of compounds, shown in Fig. 5c. The last traces of carbon appear in this zone. In zones III, IV and V which are heated above 500 degrees Cent. (932 degrees-Fahr.), the metal is completly decarburized. Fig. 4d illustrates the resistance of the nitride to prolonged etching in hot sodium picrate which may be taken to show the absence of carbon and the impossibility of confusing the iron nitride in this massive form, with the iron carbide that it resembles.

It is well to call attention to the thick intercleavage slabs of nitride which traverse the ferrite grains of Figs. 4, a and b, and their resemblance to the nitride plate or needle. The composition of the intercleavage filling is identical with that of the intergranular filling and surface film, as indicated by its structural continuity. The grain boundary contact and intercleavage course which the intruding nitride adopts, is similar to that taken by the thin plates which occupy the interior of this specimen or appear in less severely nitrogenized steels. The needle or plate form of nitride which appears in steels treated in ammonia above 450 degrees Cent. (842 degrees Fahr.) always assumes an intercleavage position and frequently is connected to a thin intergranular film. Finally the occurrence of the plates at or above 450 degrees Cent. which is the temperature at which Fe_2N forms associates their appearance with the formation of this compound. These facts strongly indicate that the plates or needles which are commonly present in nitrogenized steels, are thin intercleavage films of the nitride, Fe_2N.

Of equal interest, are the "white bordered" dark etching patches which appear in the interior of the wall in this zone. The bright border of the dark patches has been described as characteristic of nitrogen bearing steels. The source of this effect is yet a matter of speculation inasmuch as it may appear (as in Fig. 4c) in pearlitic or carbon bearing areas, and again in carbon free areas. In the former case, observations sug-



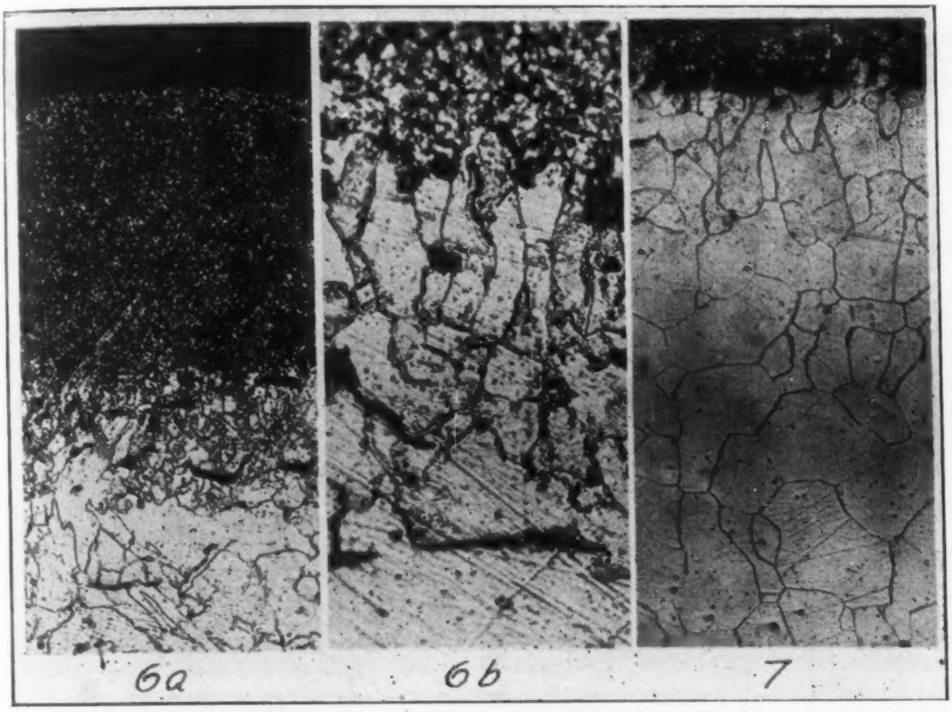
Figs. 5—a, b, c and d—Structures Prevailing in the Corroded Collar of Zone III. Same Tube as Represented in Figs. 2, 3 and 4. Fig. 5a—Structure in Spongy Layer. ×500. Fig. 5b—Darkened Band at the Junction of the Spongy Layer and Pitted Interior. ×100. Fig. 5c—Infiltration of Darkened Band Showing Grain Envelopment. Contour-like Markings Illustrate Grain Uplift. ×500. Fig. 5d,—Intergranular Pits in "Compact" Backing. ×100.

gest, as an explanation of the relation between the brightened edge and pearlitic center, a gradual replacement of the cementite (Fe_3C) by the nitride Fe_2N. The inability to detect cyanides in a sample possessing this type of structure, and the loss in carbon which is detected, indicates that a volatile hydrocarbon, is produced. A reaction summarizing the result, might be advanced, in which the action of dry ammonia upon the iron carbide in this temperature range, produces, as end products, the nitride of iron and a volatile hydrocarbon. Future research will doubtless determine the character of this reaction. In the absence of carbon, the brightened border, probably represents an iron nitride shell which might be expected to form on the exterior of the darkened, iron nitrogen solid solution, during slow cooling. The recession of the solid solution, from the ferrite matrix, during cooling, with an attendant increase in the nitrogen content of the littoral layers of the receding solution, would accumulate sufficient nitrogen along the edges to form the iron-nitride shell.

The severely corroded portion, corresponding to zone III revealed a disintegration of the compact crystalline structure into a coky or spongy mass. In the region of the failure, the disintegration had progressed completely through the wall. Fig. 5a, shows the porous texture of the spongy skeleton that remains. Figs. 5b, c and d show the structure within a specimen corresponding in degree of deterioration, to the one pictured in Fig. 3a. When fractured, the dark, spongy layer seemed to be firmly attached to the compact outer skin. The junction is shown in Fig. 5b. Within the spongy zone, and penetrating into the fissured outer skin, a darkened band appears which marks the position of the iron nitrogen solution in the structures* The solution makes its advance along the intergranular channels, gradually enveloping the grains encountered in its progress, as shown in Fig. 5b. Since this structure is confined to this zone, it seems to be defined by the ammonia concentration and temperature conditions, prevailing. A peculiar change in the surface band of the ferrite is noticeable in the region bordering the farthest ad-

*Knight and Northrup, *Chemical and Metallurgical Engineering*, volume 23, No. 23, December 8, 1920, page 1107, have reported the appearance of a pearlitic layer in carburized steel heated in ammonia at 650 degrees Cent. Similar tests at this laboratory have developed the darkened band in pure iron. The area often lacks the structural form typical of eutectics and fails in other respects to satisfy eutectic requirements.

vance of the dark constituent. An uplift of the structure in the direction of the less affected interior, produces a secondary boundary which like a contour marking, follows the outline of the dark constituent. Fig. 5c records an example of this.



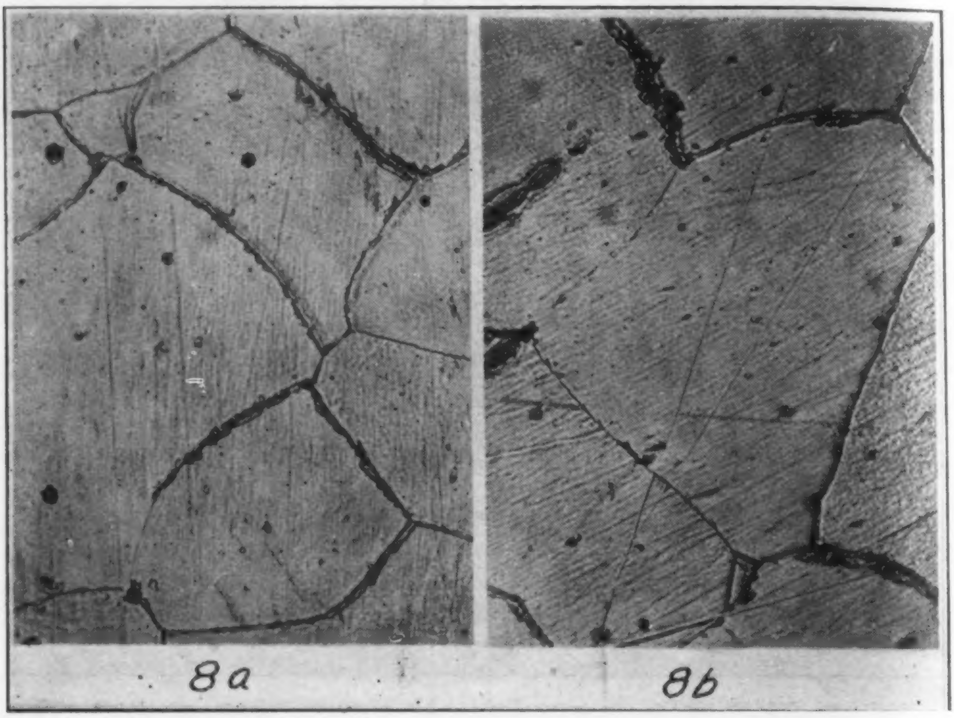
Figs. 6a and 6b—Structure in a Section Adjoining the Corroded Collar of Zone III. Fig. 6a—Spongy Edge. ×100. Fig. 6b—Grain Fragmentation at Junction of Spongy Edge with Fissured Interior. ×500. Fig. 7—Surface Attack in High Temperature, Low Ammonia Zone. ×100. Same Tube as Represented in Figs. 2 to 6.

The effect suggests an infiltration of gas into the compact grain structure, producing an expansion of the crystal lattice with an attendant swelling or decrease in density of the affected portion.

In the outer edge of the wall, the decarburized and perforated structure, shown in Fig. 5d, occurs. The structure is that of ferrite, interwoven with fissures and intergranular pits.

The occurrence of the dark band at the junction of the fissured interior with the spongy exterior, associates its presence with the severe disintegration. Apparently the disintegration consists of a decarburization and fissuring, as indicated in the interior and outer edge; followed by nitrification

marked by the darkened band; followed in turn by decomposition of the nitride so formed, which leaves the spongy, iron residue in its wake. The disintegration in a section adjoining the corroded collar of zone III shows a marked decrease in the severity of the ammonia attack. Figs. 6a and b, illustrate the



Figs. 8a and 8b—Structures in the Exhaust Portion of the Tube Show the Effect of Nitrogen and Hydrogen at High Temperatures. Same Tube as Shown in Figs. 2 to 7. Fig. 8a—Etching Fluid Exudations along Grain Boundaries Indicate Intergranular Fissuring. ×500. Fig. 8b—Another Spot, Similar to ("a") Showing Diffusion Rings Around Slag Inclusions. ×500.

structure along the exposed surface in this section. The advance of the darkened band seems to be preceded by the breaking up of the encountered grains. Mechanically, the destruction appears to progress in 3 stages.

I. Intergranular fissuring.
II. Grain dislodgment and partial fragmentation.
III. Thorough fragmentation of the dislodged grains.

The first stage consisting of an intergranular fissuring is similar to that described for Fig. 5b. The fissures penetrate completely through the wall. Fig. 6a, shows the spongy edge, which is darkened by the iron nitrogen solid solution. In

this case the contact of the fissured interior with the spongy edge, is marked by a band of broken grains. The contact is better shown in Fig. 6b. The change in the character of the disintegration is no doubt due to the lower ammonia concentration and higher temperature to which this section is exposed. In the high temperature, low ammonia regions, a slight surface disintegration and decarburization, is evident. Fig. 6a, reveals the edge of a specimen in zone IV which shows the depth of the disintegration as marked by the thin black band. A complete decarburization of the underlying metal is apparent.

The surface disintegration of zone IV does not appear in zone V at the exhaust end of the tube. The heat cracks or fissures appear to be limited to the surface of the tube. The brittleness of the metal prompted a further inspection and a close examination showed that the structure was interwoven with a net work of very fine fissures. Etched specimens, if allowed to stand, would upon examination, show thin intergranular films around the ferrite grains. These films proved to be dried exudations of the etching fluid. By observing a freshly etched surface for a few minutes a film of the etching fluid would appear along the grain contacts and gradually spread over the neighboring surface. This effect repeated at will, definitely proved the presence of intergranular fissures. Figs. 8a, and 8b, illustrate fissure exudations.

Attention might be called to the diffusion rings or halos which surround particles of embedded slag as shown in Fig. 8b. These rings apparently represent the progress of diffusion into the matrix of the decomposition products of the reaction between the slag and the gases. The micrograph shows that particles that are thoroughly embedded within the grains, are very slowly attacked.

V. Discussion of General Relations Between Temperature and the Reversible Gas-Metal Reactions

An attempt to explain the condition of the structure and its relation to the deterioration, requires a general reference to

the changes with temperature of the reversible ammonia—iron reactions:

1. $4\ Fe + 2NH_3 = 2\ Fe_2N + 3H_2$.
2. $Fe_x + 2(NH_3)_y = Fe_xN_y + 3_yH_2 + N_2$ and the ammonia equilibrium reaction;
3. $2NH_3 = N_2 + 3H_2$.

It is quite generally known that the nitride of iron, Fe_2N,

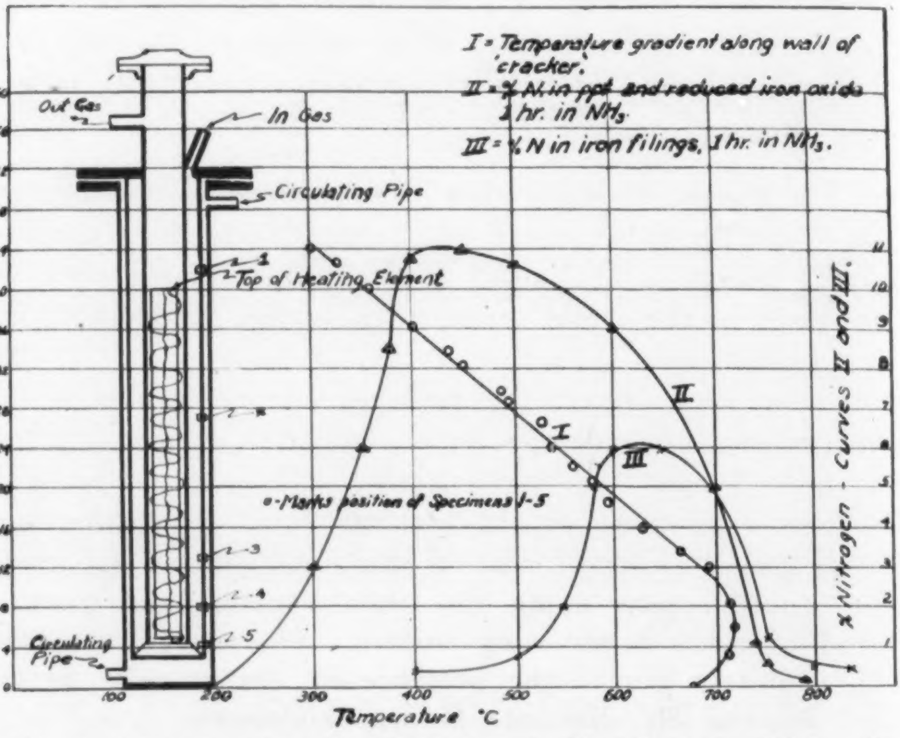


Fig. 9—Sketch of an Ammonia "Cracker" of the Two-tube Type. Third or Outer Tube Serves as a Jacket Containing Still or Slowly Circulating, Non-oxidizing Gas, such as Nitrogen, Hydrogen or a Mixture of the two. Curves II and III (after Tschischewski) Plotted against Temperature Gradient Curve I.

forms at 450 degrees Cent. (842 degrees Fahr.) when iron is exposed to a current of ammonia. Early reference to this, dates back to the work of Despretz*. The nitride is unstable above 450 degrees Cent. and its decomposition proceeds with higher temperatures. Tschischewski**, reporting the nitrogenization of iron by ammonia, obtained curves II and III of Fig. 9, for the variation in nitrogen content with temperature. The curves show a similarity in form. The lowered maximum and the displacement in the direction of higher temperatures of

*Ann. Chim. phys. 1829 Vol. 42, p. 122.
***Journal Iron and Steel Inst.* 1915, vol. XCII, No. 2, p. 47.

curve III might be expected in view of the limited time of exposure and the probable concentration gradients from surface to center, of the coarser particles of the material used. The surface of the exposed decomposer tubes should, however, conform more closely to the form of curve II, because of the extended time of exposure.

As in the conversion of nitrogen and hydrogen, into ammonia, the decomposition of ammonia involves a time factor which is a measure of the reaction velocity. The rate of ammonia decomposition, becomes very rapid in the temperature range of 450 to 650 degrees Cent. (842 to 1202 degrees Fahr.). A curve representing the rate of decomposition with changes in temperature would undoubtedly be of the 'U' shaped type with its apex at 500 to 550 degrees Cent. (932 to 1022 degrees Fahr.). The lower temperature portion of the rapid decomposition range (400 degrees Cent.) coincides roughly with the temperature at which the nitride of iron, is formed. The latter decomposes slowly in comparison to the rate of decomposition of the ammonia. For this reason, the region of maximum deterioration lies in the zone in which reaction 3 predominates.

In following the progress of the reactions with changes in temperature; it has been shown that the temperature in zone I had been too low for the formation of nitride. The quantity of ammonia decomposed, had likewise been insignificant. In zone II, evidence of the progress of the reactions 1 and 2, is visible in the formation of the surface coating, nitride plates and darkened patches. The degree to which reaction 3 had progressed is speculative, since but little decarburization is noticeable. Reaction I predominates, as indicated above; its progress probably being impeded by the thick surface coating of nitride which is formed. In zone III reaction 3 has reached its maximum velocity while reaction 1, is partly replaced by reaction 2. The solution of nitrogen and iron which is formed is not protected by a surface layer until an appreciable decomposition has occurred. Then the spongy skull that forms might retard the destruction slightly, by acting as a porous filter, and cracking the infiltering ammonia, but this protection would be negligible. Evidence of the presence of an appreciable amount of hydrogen is shown in the freedom

from carbon of this portion and of the balance of the tube. Beyond the cracking zone, the thin disintegrated layer along the surface in zone IV indicates the action of a small percentage of residual ammonia. The absence of nitrogen compounds shows that reaction 3 had begun to approach equilibrium. This same feature but lacking the surface disintegration in zone I indicates that equilibrium with respect to reaction 3, had been attained. In fact the drop in the temperature over the exhaust portion of the tube would favor the synthesis of a small amount of the available nitrogen and hydrogen.

VI. Summary

1. The failure in service of wrought iron and steel tubes employed in an apparatus used for the decomposition of ammonia, is described. The prolonged exposure of the metal to a current of hot gaseous, ammonia produces a localized disintegration, the position of which is determined by the temperature and ammonia concentration.

2. The progress of the deterioration, with temperature, is similar for both types of material. Details of the macroscopic and microscopic features of the deterioration of the metal, are mentioned in view of their importance in connection with the study of 'nitrogenized' steels.

3. The relations between temperature and the joint reactions representing the decomposition of ammonia and the nitrogenization of iron are briefly sketched to illustrate the general character of the deterioration of steel in heated ammonia.

NOTES FROM THE BUREAU OF STANDARDS

Thermal Stresses in Steel Car Wheels

SOME of the work of the Bureau of Standards in testing car wheels has been described in previous reports of the bureau. In 1920 a conference of several representative manufacturers and purchasers of steel car wheels was held at the bureau to discuss plans for conducting an investigation of the thermal stresses developed in the plates of such wheels through heating of the rim during long brake applications. As experienced railway men stated that sometimes the tread becomes heated to a dull red, it was agreed that such an investigation would be of general interest and value to the steel wheel industry.

Eight worn 33-inch wheels were furnished by the Pennsylvania railroad and nine new 33-inch wheels were furnished by several different manufacturers. One or more tests were also made on two special designs of wheels, the first with a thin plate, and the second with a straight plate. The wheels tested were representative of the five methods of manufacture in common use and were mounted in such a way that the axle was kept cool by running water while the tread could be heated by means of electrical resistor close to but electrically insulated from the tread. Thermocouples were inserted at approximately 2-inch intervals to determine the temperature distribution, while the radial stresses developed in the plate on both the face and back were indicated by means of strain-gage measurements. The tensile properties and coefficient of expansion of the material from which the wheel was made were determined in auxiliary tests. The stresses were only calculated radially on the face and back of the plate since preliminary measurements indicated that the tangential stresses were of a compressive nature and of small magnitude.

Ordinarily the tread of the wheel was heated to a temperature of about 380 degrees Cent., but in the case of two new rolled wheels and one cast wheel, the treads were heated to the highest temperature attainable with the equipment, about 500 degrees Cent. Considerably more time was required to reach this temperature than to reach the temperature of 380 degrees Cent., but the stresses were no greater. The geater strain appeared to be offset by the greater expansion resulting from the higher temperature, thus giving a flat stress time curve between 380 to 500 degrees Cent.

The most interesting features revealed in these tests may be summarized as follows: (1) None of the wheels failed; (2) When the rim is heated, the hub moves with respect to the rim inducing stresses in the plate. For the first test on new wheels these are in tension near the hub and in compression near the rim on the face, while on the back of the plate, the stresses for the same locations near the hub and rim are about equal in magnitude

but of opposite sign; (3) For worn wheels, the stresses are of the same character except near the rim on the face where very little stress is found. This difference is due to shifting of the neutral axis on the face brought about by conditions of service; (4) The maximum stresses are on the surface and slightly above the yield point of the material which averages about 50,000 pounds per square inch as determined in tensile tests; (5) A permanent set resulted only in the case of new wheels on the first test. For worn wheels and in succeeding tests on new wheels, no set was apparent, showing that stresses above the yield point were not increased by repeated heating and that through the effects of service the old wheels had been brought to a condition approximating that of the new wheels after the first heating; (6) For all forged wheels, the character and magnitude of the stresses are but little affected by the method of manufacture. Because of the corrugated plate, the stresses developed in the cast wheels were more complicated than those in the forged wheels; (7) The special rolled wheel with the thinner plate ½-inch thick developed stresses similar to those in the wheels of regular design but of somewhat greater magnitude, while the stresses produced in the special straight plate wheel were in pure tension on both the face and back of the wheels.

This work is described in detail in Technologic Paper No. 235 of the Bureau of Standards which will be available at an early date from the superintendent of documents, government printing office, Washington, D. C.

Etching Reagents for Alloy Steels

This investigation which has been in progress at the Bureau for some time has yielded the following results to date: The metallographic etching of alloy steels with the usual acid etching reagents fails to identify the different constituents that may be present in the alloy steel, such as the carbide of iron, chromium, tungsten or vanadium, tungstide of iron, and possibly complex compounds as double carbides. This is a particular importance where two or more of the constituents are present simultaneously in the microstructure as has been found to be the case with high-speed steels and iron-tungsten-carbon alloys.

It was seen early in the investigation that, on the one hand, the use of the usual inorganic acids offered little hope of success because of the general resistance of the above-mentioned constituents to the corrosive action of the acids, while, on the other hand, alkaline solutions of an oxidizing nature offered considerable promise in producing distinctions by means of etching characteristics. A little experimental work was next carried out on various alkaline solutions with and without the use of oxygen gas or oxidizing agents, the results of this work being the develop-

ment of a new etching reagent, namely, a potassium permanganate and sodium hydroxide mixture.

With the object of establishing the identity of the metallographic constituent known or believed to be present in the microstructure by noting its behavior toward the various etching reagents, etching tests were made on various amounts of the alloying element and of carbon. For this work a number of etching reagents of an alkaline nature, among which were several well-known reagents, such as sodium picrate, Yatsevitch's reagent, etc., were used. Heat-tinting was also tried. The method of sequence etching or etching with two or more reagents in succession without any repolishing of the specimen between the etchings was used with success in cases where more than one constituent is present in the microstructure, as in high-speed steels.

The results obtained so far show that it is possible, by proper selection of the etching reagent, to determine in a satisfactory manner the presence or absence of the different constituents in the micro-section and also to distinguish between several of the constituents when two or more are present in the same micro-section, as, for example, cementite and chromium carbide, or cementite and iron tungstide. No method has as yet been found for distinguishing between chromium carbide and tungsten carbide other than from a consideration of the shape of the particles which these constituents have been found to assume should both occur in the same micro-section.

Gases in Metals

Tests conducted at the Bureau of Standards on the completeness of recovery of oxygen from oxides of iron and silicon in the vacuum fusion method for gases and metals have indicated complete reduction and recovery in both cases. Other oxides which may be present in steels are now being tested. Through the co-operation of a manufacturer of malleable cast iron, some tests have recently been made which indicate that the results for oxygen by the Ledebur method on white cast iron are of little value because of the surface oxidation of the sample during its reduction to a finely divided form. The apparent oxygen content of the metal as a fine powder is about 100 times, and as a coarse powder about 50 times the true oxygen content of the material, as given by vacuum fusion analysis on a solid sample.

Heat Treatment and Properties of Magnet Steels

The Metallurgical and Electrical Divisions of the Bureau, in co-operation, are beginning an investigation to determine the effects of various heat treatments upon the characteristic properties of the steels now used commercially or suggested for use in the manufacture of permanent magnets. During the past month

about 10 samples were hardened, and it is hoped that they will soon be ready for the first magnetic tests.

Non-Destructive Testing of Wire Rope

The Bureau of Standards is about to undertake an investigation of the possibilities of using non-destructive methods for testing wire rope with special reference to hoisting rope. Present methods of inspection are unsatisfactory and do not unfailingly tell when it is necessary to remove the rope from service. The object of this investigation is to develop, if possible, some method by which an actual test can be made to determine the condition of the rope with respect to its deterioration in service, without destroying it. An advisory committee is being organized which will be composed of representatives of the principal interests connected with the manufacture, use, and testing of wire rope, and the first meeting of the committee was held at the Bureau on June 16 for the purpose of discussing plans and methods of procedure in the work.

Steel for Brinell Balls

In measuring the hardness of metals by the Brinell method, a hardened steel ball is forced into the specimen by hydraulic pressure, the amount of penetration serving as an indication of the hardness of the sample. Difficulty has been found in measuring the Brinell hardness of steel having a hardness over 500 B. h. n. An attempt has been made by the Bureau for the past 3 or 4 years to obtain a very hard steel which will carry the load of 3000 kg. without fracture, but up to the present without success. Tungsten carbide has been suggested, but it has been impossible to obtain this material in suitable condition in either this country or Germany. Recently a very hard vanadium steel made at the Bureau's laboratories has been tried and shows promise of success. More of it will be made, and if future experiments are successful, an important advance in the art of hardness testing may result.

Scratch of Hardness of Copper

The Bureau of Standards is conducting an investigation of the instrument used for the determination of the scratch hardness of metals, and in connection with this work, considerable attention has been given in respect to the affect of various amounts of cold working on the hardness of copper. The results obtained in cold rolling very pure, electrolytic, unmelted copper and also ordinary commercial copper indicate clearly that the early stages of the deformation of the metal harden it very rapidly. The maximum degree of hardness is soon reached, however, and a reversal occurs, the metal becoming very appreciably softer as the deformation process is continued, so that the metal in

its final condition after cold rolling is completed is softer as measured by the scratch hardness method than in its initial state. These results were confirmed by tests made on the same material by the micro-Brinell method. Annealing cold-rolled sheets at a low temperature (100 degrees Cent.) softens the material appreciably, but the general form of the hardness deformation curve is not affected.

The work will be extended to a few other metals to determine whether this behavior is peculiar to copper or more general in its nature.

THE CRYSTALLIZATION OF IRON AND ITS ALLOYS

Concluded from Page 45

mal critical range, and through that range so as to obtain the cast structure most suitable to our purpose, namely, a net work structure, a Widmanstätten structure or a "mixte" structure. We should bear in mind that dendritic segregation is not removed by the usual heat treatments, and that when the steel ingot is subjected to hot working, between the solidus and the thermal critical range, a banded structure is necessarily produced and directional properties imparted which will be the more pronounced the greater the reduction of the cross section. We should, therefore, abandon the belief that the more we work steel the more we improve its physical properties. If the finished implement is to be subjected to transverse stresses, excessive reduction is very detrimental whenever persistent dendritic segregation exists.

The author desires to record here his appreciation of the work performed in his laboratory during the last two years by E. L. Reed, instructor in metallurgy, and Carnegie research scholar, and by V. D. Krivobok and D. C. Lee, candidates for the degree of Doctor of Science, who have conducted most of the experiments described in this paper and many others which may bear fruit later. Their industry and enthusiasm have been an inspiration.

NOTES FROM THE BUREAU OF MINES

Improving the Efficiency of the Blast Furnace

THROUGH its investigations into (1) the reactions taking place at certain zones in the blast furnace, (2) the effect and elimination of sulphur in coke, and (3) the use of oxygenated or enriched blast, the Department of the Interior, working through the Bureau of Mines, hopes to reach definite conclusions which will be of considerable benefit to the iron and steel industry.

At its Minneapolis experiment station the Bureau of Mines has made several smelting campaigns, these including the regular sampling and determination of gases at fixed planes in the blast furnace, from which certain deductions can be made. Another run is under way during the past month. Trials are also being made with oxygenated blast.

The behavior and elimination of sulphur in coke is being studied at the bureau's Pittsburgh experiment station, this revealing some interesting facts regarding the absorption of sulphur by the iron inside the furnace.

The possibilities of using oxygenated blast are many, and include (1) the elimination of hot stoves; (2) the use of an excess of coke to prevent chilling and freezing; (3) the elimination of sulphur; (4) allowance of the utilization of high-phosphorus ores; (5) improvement in Bessemerizing; and (6) lower costs. A committee of ten metallurgists, chemists, and engineers, including five Bureau of Mines men, is studying this phase, and will shortly issue a preliminary statement thereon.

Shells In Strip Steel

The result of an analysis of data on open-hearth practice resulting in shelly strip steel, made by F. B. Foley, metallurgist of the Department of the Interior, at the Mississippi Valley experiment station of the Bureau of Mines, Rolla, Mo., showed that heats which produce shells are shorter heats, that they take more ore, and less spar and that they give a lighter ladle skull than those that produce metal free from shells. The indication is that shells are the result of running the heat in the open-hearth too hot and bringing down the carbon too fast by oreing. The metal is thus apparently over-oxidized.

Coal-Fired Furnaces

Manufacturers and operators of the larger coal-fired furnaces can not afford to disregard the possible advantages of pulverizing their coal before burning it, states John Blizard, fuel engineer of the Department of the Interior, in Bulletin 217, recently issued by the Bureau of Mines. The bulletin, which

contains information, regarding the preparation, transportation and combustion of powdered coal, is published through the courtesy of the Canadian Department of Mines, for whom the bulletin was originally prepared.

Powdered coal has been successfully applied, and is commonly used in open-hearth furnaces; busheling and puddling furnaces; continuous-heating furnaces for blooms and billets; furnaces for heating, reheating, and forging, annealing furnaces for malleable iron and steel castings and plates; sheet and pair and annealing furnaces and tin pots; galvanizing pots; soaking pits; ore roasting and volatilizing; copper-ore roasting and smelting; the zinc industry; the gold and silver industry; calcining kilns; lime burning; refractory materials; and also in the fertilizer industry. It is used more than any other fuel in the cement industry and has been successfully applied for steam raising. Whenever powdered coal has displaced hand firing the coal consumption has been reduced considerably.

By the term powdered coal is meant coal subdivided so that it may be burned in suspension when mixed with the necessary supply of air and may be conveyed easily by means of a screw conveyer, by compressed air, or suspended in a steam of low-pressure air to the furnace.

Since the coal has to be pulverized, it is usually better to purchase slack coal, which is usually cheaper and costs less to pulverize.

The requisite composition of the coal depends upon many factors. Practically all coals from lignite to anthracite, and even coke breeze have been pulverized and burned. But anthractite and coke breeze require more energy to pulverize them than softer coals, and low-volatile coals are difficult to ignite and must be burned in specially designed furnaces.

One of the principal difficulties in burning powdered coal lies in the disposition of the ash; and for this reason it is desirable also to use a coal which contains little ash and that melting at a comparatively high temperature.

The power used to pulverize and convey similar coals to the burner is approximately proportional to the weight of the coal pulverized, and it is clear that the pulverizing and conveying costs will, therefore, be greater per heat unit delivered the lower the calorific value of the coal.

A powdered-coal plant consists of apparatus which converts raw coal into powder and conveys it to the furnace, into which it is delivered as required and burned in suspension. The systems used to accomplish this may be divided into two classes: (1) The unit system, in which one machine prepares and delivers the coal to the furnace with the necessary air for combustion, and (2). the multiple system, in which the coal is

prepared in one building and transported to another building wherein is situated the furnace in which the coal is to be burned.

The principal advantages over hand and stoker firing lie in the comparative ease of conveying coal to furnaces and in the practically complete combustion of the coal, with little excess air, in close contact with the material to be heated, thus avoiding the convection, radiation, and excess-air losses which accompany hand or stoker-fired furnaces placed outside reverberatory and many other furnaces. For this reason the most successful field of use of pulverized coal installations has been for those purposes where they have replaced externally fired furnaces. For purposes such as steam raising, where the burning coal can give up heat directly by radiation to the boiler heating surface, there is, therefore, less opportunity for reducing the fuel consumption by burning powdered coal instead of burning coal on a grate, since the losses which may be reduced by substituting powdered coal firing for hand firing or stoker firing are those only which are due to incomplete combustion and using excess air. These losses, however, are not inconsiderable.

Certain drawbacks to the use of powdered coal are cited by the author of the bulletin. Before powdered-coal firing can compete successfully with grate firing it is obvious that the gain due to the smaller consumption of powdered coal must offset the cost of preparing, conveying, and burning it.

There is a further disadvantage with powdered coal. In grate firing the ash is left on the grates and in the ash pit. But with powdered coal the ash is blown into the furnace, out through the stack, and with some badly designed furnaces out through openings in the furnaces. It may also form a troublesome slag, and fill up the flues so as to impede the draft.

On the whole, powdered-coal plants can not be said to be clean. There are fairly clean powdered-coal plants; but generally, though not universally, a plant using powdered coal is dirtier than a grate-fired plant.

Powdered coal is better adapted for firing stationary water-tube boilers than other boilers. With these boilers furnaces of sufficient size and of the correct shape may be constructed, and the gases pass through no tubes wherein ash may settle to obstruct the draft and shield the heating surface. It has been found difficult to burn powdered coal in locomotive and cylindrical marine boilers because the combustion space is too small to permit the coal to be burned completely.

Although men have been killed by explosions and fires in powdered-coal plants, the causes of such accidents are known and precautions may be taken that they may not recur.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment — Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions

NEW QUESTIONS

QUESTION NO. 86—Can ingotism in steel be removed by subsequent rolling or forging?

QUESTION NO. 87—What is the reason for the distortion of gears made of S. A. E. 3120 steel after carburizing according to recommended heat treating practice of the S. A. E?

ANSWERS OLD QUESTIONS

QUESTION NO. 69. Is sulphur up to 0.10 per cent detrimental to the quality and physical properties of an automotive steel?

QUESTION NO. 71. How do the physical properties compare between a 0.35-0.45 per cent carbon acid open-hearth steel and an alloy steel of either 3.5 per cent nickel or 1.5 per cent nickel and 0.50 per cent chromium neither heat treated?

ANSWER. By J. S. Vanick, research operator, fixed nitrogen research laboratory, department of agriculture, Washington, D. C.

The approximate tensile properties of the annealed steels of the composition mentioned, are as follows:

Composition Carbon per cent	Nickel per cent	Chrome per cent	Tensile strength lbs. per sq. in.	Yield point lbs. per sq. in.	Red area per cent	Elong. 2 inches per cent
.35	..	..	64,000	48,000	62	29
.45	..	..	71,300	57,500	54	23
.35-.45	3.5	..	73,000	58,000	50	23
.35-.45	1.5	.60	75,000	60,000	45	20

No comparison can be made between "untreated" steels, if a strict interpretation of the term "heat treat" is used. Since manufacturing processes vary, untreated steel would mean steel from any source, in bar, billet, or finished form, which had not received the attention necessary to eliminate differences in condition introduced during the manufacturing process.

No steel should be used without being annealed either by the user or by the manufacturer. Most steels in bar sizes are subjected to a "mill anneal" by the manufacturer. Many products receive treatment equivalent to annealing by being finished at suitable temperatures and cooled under carefully controlled conditions. In any case, a comparison of tensile properties is not justified until a common level, with respect to the condition of the steel, is reached and this level in its most simple form is attained in the annealed product.

QUESTION NO. 72. What elements are conducive to good electric butt-welding of steels?

QUESTION NO. 73. Does electric butt-welding destroy the physical properties developed in a steel which has been heat treated prior to the welding operation?

QUESTION NO. 74. Why shouldn't a bar of steel rolled from a locomotive axle be better than one rolled direct from the billet made from the original ingot?

QUESTION NO. 76. Why are cold drawn carbon and high-speed steel sometimes supplied with a copper coating? Does this coating affect the steel in any way, or is it merely a lubricating agent in the drawing process? Is it necessary or desirable to remove the coating before hardening?

ANSWER—By B. F. Weston, Jones & Laughlin Steel Corporation—S. S. Works, Beaver Falls, Pa.

The cold drawing of steel presents a condition requiring great efficiency in lubrication, as may be imagined, and while many substances are used in drawing ordinary soft grades of steel, the use of some substance entirely preventing the "galling" and scratching of the bar being drawn in the case of harder material.

A heavy grease of the lime or aluminum soap type may be used, a light copper coating is desirable, which would not be likely to injure the steel except for use in some special

cases. The copper acts only as a lubricant, and while it is not necessary to remove the copper coating before hardening, the writer believes it desirable.

QUESTION NO. 82. What analysis steel is most suitable for punching out hot work on upsetter in drop forge shop?

ANSWER. The most suitable steel for piercing-punches and shear-dies used for hot work on upsetting machines is one having the following approximate analysis:

Carbon per cent	Manganese per cent	Chromium per cent	Vanadium per cent	Tungsten per cent
0.50	0.30	2.75	0.40	14.00

Phosphorus and sulphur as low as possible.

Preheat to 1600-1700 degrees Fahr., heat to 2100-2150 degrees Fahr., quench in oil, draw at 1050 degrees Fahr.

Should a steel be required to withstand severe shock in addition to heat, the following approximate analysis may be found more suitable:

Carbon per cent	Manganese per cent	Chromium per cent	Vanadium per cent	Tungsten per cent
0.25	0.30	3.25	0.25	8.00

Phosphorus and sulphur as low as possible.

Preheat to 1600-1700 degrees Fahr., heat to 220-2350 degrees Fahr., quench in oil, draw at 1050 degrees Fahr. .

Another analysis suitable for some kinds of hot upsetting work is approximately:

Carbon per cent	Manganese per cent	Chromium per cent	Vanadium per cent	Tungsten per cent
0.50	0.35	1.50	0.20	2.50

Phosphorus and sulphur as low as possible.

Heat to 1750-1800 degrees Fahr., quench in oil, draw at 900-1050 degrees Fahr.

The following chrome steel has also been found satisfactory for some kinds of hot upsetting work:

Carbon per cent	Manganese per cent	Chromium per cent	Vanadium per cent
0.85	0.40	3.50	0.15

Phosphorus and sulphur as low as possible.

QUESTION NO. 83. In annealing high carbon tool steel in an open fire furnace 6′ x 12′ is it likely that sulphur would be imparted to the steel by the use of producer gas made from coal unusually high in sulphur, say around 1.50 to 2.00 per cent?

QUESTION NO. 84. What is the effect on the steel being forged, through the use of high velocity blows during drop forging?

ANSWER—By Henry Hayes, London, England.

Though the statement may not be readily accepted, it has been found by experience that high velocity blows fill the die better and use less material. In a drop hammer, the velocity of the falling weight is determined by the height of the fall. In the steam drop hammer of the direct-acting type, the stroke is shorter, but is compensated for by the steam pressure behind the piston. As the velocity increases with the steam pressure the tup strikes the work with a higher velocity than in the gravity drop stamp. The lift off is also quicker in the steam hammer, therefore the period during which the heated steel is in contact with the dies is reduced—greatly to the advantage of the dies.

The problem of the speed of the blow is one which has not yet received the metallurgical and mechanical consideration that its importance warrants. It is known that there is a great difference between the work performed by a hydraulic press and a steam or drop hammer; and when this is analyzed critically it resolves itself into a question of the time during which the work takes effect.

In the case of hydraulic press work, every molecule of the metal has ample time to transfer the push to its neighbors, and not much work is expended in internal friction. With a high velocity blow, however, there is little time for the transfer of energy and much work is expended in overcoming the high internal resistance, and is converted into heat. It is thus possible to have a job coming out of the dies at a considerably increased temperature.

Drop forgings can be classified under two headings, those of large area requiring maximum horizontal flow, and those in which the flow is mostly vertical. In the first case every inducement must be adopted to allow the metal to run away, such as highly polished die surfaces and ample lubrication. In the second case, where vertical flow is desired, it is necessary to create conditions to increase the resistance to horizontal flow, so that the plastic metal may be squirted or extruded into the unfilled die spaces. If the flat surfaces of the die are rather rough this will increase the frictional resistance which will be greatly reinforced when the fin begins to form. Another important factor is that work which is applied slowly (as by low velocity blows) is selective, having more time to search for

(*Continued on Page* 108)

Reviews of Recent Patents

1,447,356. Die Support for Wire-Drawing Machines. Charles H. Osland, Worcester, Mass., assignor to the O. & J. Machine Company, a corporation of Massachusetts.

This patent refers to a wire-drawing device, the combination with a bracket provided with a pair of upwardly extending sides, each perforated, a guide pin extending through each perforation in a direction parallel to the direction of the wire, said pins and sides being located at a distance apart, a spring on each of said guide pins bearing against said upwardly extending sides and a box for lubricant having ears on opposite sides provided with perforations through which said pins pass and having means for preventing the ears from being pushed off the pins, said springs bearing against said ears of a wire drawing die supported at the end of said box beyond the springs, said box having means by which the die is firmly secured in position and also provided with flanges oppositely located and engaging the surfaces of said upwardly extending sides opposite the springs, whereby the whole box with its die is yieldingly mounted and is guided to move with the wire or against it in parallel relationship to it at all times.

1,447,517. Automatic Temperature-Control Means for Electric Furnaces. Thomas Andrew Reid, East Orange, N. J., assignor to Electric Heating Appartus Company, Newark, N. J.

This invention refers to the combination with an electric furnace having a single source of electrical energy, of variable voltage contacts and a coacting switch arm to control the input to said furnace without interrupting the flow of current therethrough, a pyrometer having a movable contact element and spaced stationary contact elements of opposite sign, a motor to operate said switch-arm in either direction of its movement for varying the voltage of current supplied to the furnace, motor circuit including said pyrometer, and an independent source of energy for the control of said motor.

1,447,817. Art of Casting Metals. James M. Perry, Detroit, Michigan, assignor of two-thirds to himself and one-third to Horace G. Seitz, Detroit, Mich.

This patent relates to an art of casting metal for the production of castings of generally uniform cross-section in the direction of length of the casting, and wherein the casting is of a comparatively thin-walled type, the method of eliminating imperfections of the bubble or hold type therefrom which method consists in moving the imperfection sources from the poured metal to a waste zone by increasing the normal

speed of travel of the sources in the direction of natural movement thereof to an extent sufficient to carry the sources to such zone prior to solidification of the metal.

1,447,909. Welding Machine. James Hall Taylor, Oak Park, Ill.

This invention comprises the combination of heating apparatus for heating the work to be welded, welding surfaces between which the heated work is welded, and a one cycle stop mechanism operable to move the work between said heating apparatus and said welding surfaces.

1,448,388. Electric-Furnace Resistor. Ora A. Colby, Irwin, Pa., assignor to Westinghouse Electric & Manufacturing Company, a corporation of Pennsylvania.

This invention relates to the combination with a plurality of walls surrounding a furnace chamber, of a resistor in said chamber comprising a plurality of dished refractory electrical-conducting members, granular resistor material in each of said dished refractory members and resilient means for maintaining said dished members in interlocked position in said furnace chamber free of said walls.

1,448,480. Apparatus for Operating Furnace Doors. Lester D. Bedell, Bethlehem, Pa.

This patent refers to an apparatus for operating furnace doors which comprises the combination with a vertically movable door, of a movable lifting member connected thereto, and means for counterbalancing said door and for moving it through connection with said lifting member comprising a counter-weight of materially less weight than the door, differential operating and supporting mechanism connecting the end of said member and means in a fixed position for applying power to said operating and supporting means to cause movement of said door and counter-weight in either direction at different speeds.

1,448,684. Laminated Super-refractory Article. Milton F. Beecher and MacDonald C. Booze, Worcester, Mass., assignors to Norton Company, a corporation of Massachusetts.

This relates to a laminated refractory article having a facing of bonded refractory material, a reinforcing backing layer of ceramic material which is reactive with an ingredient of the facing, and a neutral intermediate layer intimately joined to and separating the facing and backing layers.

1,448,701. Forging Furnace. Harry O. Breaker, Winthrop, Mass., assignor to Industrial Furnace Corporation, Boston, Mass., a corporation of Massachusetts.

The above refers to a forging furnace which comprises a combustion chamber provided with a movable hearth above the combustion chamber, and with an adjustable longitudinal opening therein for the escape of the products of combustion.

News of the Chapters

BOSTON CHAPTER

The Boston chapter of the American Society for Steel Treating held a meeting on May 24th which was attended by about sixty members and guests. At this meeting the following new officers were elected for the ensuing year: chairman, H. E. Handy, vice-chairman, V. I. Homerberg, sec.-treas., G. E. Davis. The retiring chairman and secretary with the new officers will comprise the executive committee and it is felt that with a new start the chapter may be brought to the front.

CHICAGO CHAPTER

The Chicago chapter of the American Society for Steel Treating held a regular monthly meeting on May 10, at the City Club, 315 Plymouth Court. The speaker of the evening was E. W. Ehn, metallurgist, Timken Roller Bearing Co., who presented an illustrated talk entitled "Carburizing and Hardening Qualities of Steel as Influenced by Deoxidization of the Steel When Made." Mr. Ehn having made an exhaustive study of this subject gave much valuable information on the carburizing and hardening of steel, and a very lively discussion was participated in by the large number in attendance.

At this meeting the following members were elected to serve for the ensuing year: chairman, F. G. Wheeler, Miehle Printing Press & Mfg. Co., vice-chairman, R. G. Guthrie, Peoples Gas Light & Coke Co., secretary-treasurer, Arthur G. Henry, 1440 W. Lake St. The following executive committee was also elected: V. A. Hain, D. G. Haines, Wilbur Patrick, and W. H. Potter.

The chapter held its second annual outing on Saturday, June 9, at the Hartmann House, Wheeling, Illinois. The members were transported by automobile to Wheeling, where a chicken dinner was served to them at 2:30 p. m. The large

grounds of the Hartmann House was at their disposal and plenty of entertainment was provided. A most enjoyable afternoon was had by all.

CINCINNATI CHAPTER

The Cincinnati chapter of the American Society for Steel Treating held their June meeting on the 14th of the month. This meeting also included an inspection trip at 2.30 p. m. to the Pollak Steel Company. Dinner was then served at 6:00 p. m. at the Ohio Mechanics Institute, and the meeting followed at 7:30 at the same place. The paper of the evening entitled "The Impurities in Steel" was given by Dr. J. Culver Hartzell, chairman of the chapter. Dr. Hartzell gave many instructive points with reference to the impurities found in steel and a lively discussion followed.

An enjoyable afternoon and evening was spent by all.

At the chapter meeting held on May 10th, the following members were re-elected to serve on the executive committee: E. W. Detraz, Edward Gardner, C. H. Waldo, C. J. Wersel. W. R. Klinkicht was elected in addition.

DETROIT CHAPTER

At the chapter meeting held on May 29th the election of new officers was held and resulted in the following elections: chairman, J. M. Watson, Hupp Motor Car Co., vice chairman, W. P. Woodside, Studebaker corporation, secretary-treasurer, W. G. Calkins, Detroit Twist Drill Company. The following executive committee was also elected to serve for the coming year: Robert Atkinson, Halcomb Steel Co., Edmund Blasko, Ford Motor Co., H. G. Peebles, Detroit Steel Products Co., R. C. Banks, Maxwell Motor Co., W. E. Blythe, Driver-Harris Co., H. M. Northrup, Hudson Motor Car Co.

HARTFORD CHAPTER

At the May meeting of the Hartford chapter, the following members were nominated and elected to serve for the coming year: chairman, J. J. Curran, vice-chairman, C. M. Blackman, secretary-treasurer, L. A. Lanning. The executive committee is as follows: Chas. A. Allen, F. R. Downs, J. C. Kielman, R. F. V. Stanton, R. W. Woodward, and A. H. d'Arcambal.

INDIANAPOLIS CHAPTER

During the May meeting of the Indianapolis chapter the members of the chapter elected as their officers for the ensuing year H. B. Northrup, metallurgist with the Diamond Chain & Mfg. Co., as chairman and R. Robert Smith, of 1535 Naomi St., as secretary-treasurer.

J. M. WATSON
Chairman—Detroit Chapter

H. B. NORTHRUP
Chairman—Indianapolis Chapter

LOS ANGELES CHAPTER

The Los Angeles chapter of the American Society for Steel Treating held a meeting on Thursday, June 6th, at the offices of the Westinghouse Electric & Manufacturing Company, 418 South San Pedro Street, at 7:30 p. m. The speaker scheduled for this meeting, Mr. Harwood, was unable to attend, and consequently A. B. Denny, mill superintendent, Columbia Steel Corporation, presented a paper entitled "Open-Hearth Steel." Mr. Denny gave a very capable presentation and brought out

many interesting points about the manufacture of open-hearth steel. The entertainment committee was on hand and a very enjoyable evening was spent by all.

LEHIGH VALLEY CHAPTER

The Lehigh Valley chapter of the American Society for Steel Treating recently elected the following members to serve for the coming year: chairman, A. P. Spooner, vice-chairman, G. C. Lilly, secretary-treasurer, B. F. Shepherd. The executive

A. P. SPOONER
Chairman—Lehigh Valley Chapter

committee is as follows: W. H. Laury, W. R. Shimer, F. P. Martin, A. C. Moyer, S. P. Koch, H. S. Brainerd, A. E. Fowler, B. H. DeLong and R. H. Christ.

NEW HAVEN CHAPTER

According to reports from the New Haven chapter, the best meeting which the chapter ever held took place Friday evening June 15, 1923.

The meeting was held at the Wilcox Pier Restaurant, Savin Rock Park. This meeting was primarily for the purpose of having a good time. A shore dinner was served at 6:30 p. m. and all hands enjoyed a good old feed. The cabaret show and music were excellent, as was also the thoughts which were developed by the speaker, E. H. Webb, president of the Webb Wire Works, New Brunswick, N. J.

Everybody was out for a good time and thus added to the committee's efforts very materially in realizing a wonderful time.

Fred J. Dawless being considerable of a song writer introduced his version of Mr. Gallagher and Mr. Shean and the boys fell in line and enjoyed his efforts very much. His verses are as follows:

Mr. Gallagher and Mr. Shean

1

Oh! Mr. Gallagher, Oh! Mr. Gallagher
Hello, what's on your mind this morning Mr. Shean,
Ev'ry body's making fun
Of the way our country's run
All the papers say we'll soon live Eur-o-pean.
Why Mr. Shean, Why Mr. Shean
On the day they took away our old canteen
Cost of living went so high
That it's cheaper now to die,
Positively Mr. Gallagher,
Absolutely Mr. Shean.

2

Oh! Mr. Gallagher, Oh! Mr. Gallagher
Once I think I saw you save a lady's life,
In a rowboat out to sea
You were a hero then to me
And I thought perhaps you've made this girl your wife
Oh! Mr. Shean, Oh! Mr. Shean
As she sunk I dove down like a submarine
Dragged her up upon the shore
Now she's mine forever more,
Who, the lady Mr. Gallagher?
No, the rowboat Mr. Shean.

3

Oh! Major Hill, Oh! Major Hill
You're the finest singer we have ever heard.
Everybody says it's fine
When you sing "Sweet Adeline"
In a way that sounds exactly like a bird.
Oh! Major Hill, Oh! Major Hill
What is it that makes you sing so deep and full
Is it eating clams and fish,
Or some other tasty dish
Or perhaps it is a beverage
Won't you tell us Major Hill?

YES! We Have No Bananas

Yes! We have no bananas
We have no bananas today.
We've string beans and Hon-ions
cab-BAH-ges and scallions
And all kinds of fruit and say—
We have an old fashioned to-MAH-to
Long Island po-TAH-to
But YES! we have no bananas,
We have no bananas today.

YES! We have no steel troubles
We have no steel troubles today.
We once had a die break
It took weeks to make
But now that's all passed away
We have the good old Steel Treaters,
All good heavy eaters.
YES! We have no steel troubles,
We have no steel troubles today.

NEW YORK CHAPTER

At the New York chapter meeting held on May 16th the election of officers took place and the following have been elected to serve for the coming year: chairman, Sam Tour, metallurgist, Doehler Die Casting Company, Brooklyn, N. Y., vice-chairman, E. E. Thum, associate editor, *Chemical & Metallurgical Engineering,* New York City, secretary-treasurer, T. N. Holden, Jr., chief chemist, E. W. Bliss Company, Brooklyn N. Y. The following executive committee was also elected: P. D. Merica, International Nickel Co., New York City, W. B. Kopfer, Combustion Utlities Corp., Brooklyn, N. Y., K. B. Millett, Griscom-Russell Company, New York City, R. L. Angell, E. W. Bliss Company, Brooklyn, N. Y., H. J. Fischbeck, De La Vergne Machine Company.

The chapter held a meeting on June 20th at 8:15 P. M. in the Assembly Room of the Merchants Association of New York. The speaker of the evening was S. W. Miller, Union Carbide & Carbon Company, who chose for his subject, "The Application of the Oxyacetylene Torch to Heat Treatment." Mr. Miller gave a very capable presentation, dealing especially with the application of the oxyacetylene torch to the hardening and tempering of tools. Following the paper a lively discussion took place out of which many interesting and instructing points were developed.

The usual dinner was served at 6:30 p. m. in the Post Keller Restaurant.

PITTSBURGH CHAPTER

The Pittsburgh chapter of the American Society for Steel Treating held a meeting on Tuesday evening, June 5th at 8:00 p. m. in the Hawiian Room of the Wm. Penn hotel. The paper of the evening was presented by John M. Lessells, research engineering department, Westinghouse Electric & Manufacturing Co., who chose for his title "Some Remarks on Static and Dynamic Forms of Testing." Mr. Lessells presented his paper in a very capable manner, which brought forth a lively discussion.

PHILADELPHIA CHAPTER

The May meeting of the chapter was held on the 25th of the month at the Engineers' club.

The program for this evening consisted of a paper by Chas. E. Carpenter, president, E. F. Houghton & Co., entitled "What the Society Means to the Sustaining Member," and W. H. Eisenman, national secretary, spoke to the members on "What the Society Means to the Executive."

JOHN J. CROWE
Chairman—Philadelphia Chapter

At this meeting John J. Crowe was elected chairman and Arthur W. F. Green, secretary-treasurer for the ensuing year.

ARTHUR W. F. GREEN
Secretary-Treasurer—Philadelphia Chapter

PROVIDENCE CHAPTER

The Providence chapter of the American Society for Steel Treating held its regular monthly meeting on May 24, at 8:00 p. m., in the rooms of the Providence Engineering Society, 44 Washington Street. This meeting was in the nature of a round table discussion on problems of interest to all heat treaters, and proved highly satisfactory as the discussions brought out many instructive points.

The election of officers was held at this meeting, the chairman, F. H. Franklin, and the secretary-treasurer, W. H. Hunt, being re-elected, while I. E. Waechter was elected vice-chairman. An executive committee was also elected which consisted of the following members: F. N. Macleod, A. H. Annan, O. N. Geer, C. Peterson, and J. E. Wiggins.

ROCKFORD CHAPTER

At the Rockford chapter meeting held on May 18th, election of officers took place, at which time the following members were elected: chairman, Chas. Cotta, Cotta Gear Company, vice-chairman, G. Aldeen, National Locke Co., secretary-treas-

urer, J. B. Frederick, Barber-Colman Co. The executive committee consists of John Nelson, Martin Lundstrom, Arthur Memering, O. T. Muehlemeyer and R. M. Smith.

SOUTH BEND CHAPTER

The South Bend chapter of the American Society for Steel Treating held a meeting on May 9th at the Chamber of Commerce Building, at which time the following new officers were elected to serve for the coming year: chairman, Wm. J. Harris, first vice-chairman, W. F. Newhouse, second vice-chairman, V. R. Roberts, secretary-treasurer, Sam Shagaloff who was re-elected. The following executive committee was also elected: R. D. Allen, R. M. Holmes, J. A. Kingsbury, C. E. Ritchie, R. E. Lewton, and J. Nugent.

There were two papers presented at this meeting, the first being given by J. A. Kingsbury, entitled "The Selection of Tool Steels." The second paper was presented by C. P. Richter, who talked on "Oxygen and Steel." These two papers were very well presented and brought forth much interesting discussion.

SPRINGFIELD CHAPTER

The Springfield Chapter of the American Society for Steel Treating held its June meeting on the first of the month in the Chamber of Commerce Rooms, 47 Worthington Street. The speaker for this evening was R. J. Allen, Rolls-Royce Company of America, who chose as his subject "Steel from the Ore to the Finished Product." Mr. Allen brought out many interesting points and specimens of steel in the various stages of manufacture were shown.

The election of officers was held at this meeting and resulted in the following elections or re-elections: chairman, Edson L. Wood, Met., Springfield Arsenal, Springfield, Mass.; vice-chairman, V. T. Malcolm, Met., Engr., Chapman Valve Mfg. Co., Indian Orchard, Mass.; secretary-treasurer, E. L. Woods, Ind. Engr., Springfield Gas Light Company, Springfield, Mass., who was re-elected. The members of the executive committee are R. J. Allen, R. G. Robinson and F. R. Matthews.

SYRACUSE CHAPTER

The Syracuse Chapter of the American Society for Steel Treating held a meeting on Friday evening, May 25th at the Uhrig's Restaurant, which was attended by about 75 members and guests. The election of officers was held at this meeting which resulted in the following elections: chairman, F. C. Rabb, Brown Lipe Chapin Company; vice-chairman, F. A. Wheeler, H. H. Franklin Company, secretary-treasurer, R. L. Manier, Syracuse Lighting Company. The following executive committee was also elected: H. J. Stagg, Halcomb Steel Company, R. F. Smith, E. F. Houghton & Co., E. V. Clark, H. H. Franklin Company, J. C. Doty, Halcomb Steel Co., W. F. McNally, New Process Gear Corporation.

The usual dinner was served at the Yates Hotel preceding the meeting.

TORONTO CHAPTER

The Toronto chapter of the American Society for Steel held its regular monthly meeting on Friday evening May 25, 1923.

The speaker for this meeting was Prof. O. W. Ellis of the University of Toronto, who presented a very capable and interesting paper entitled "Some Mysteries of Steel Treating Simply Explained for the Practical Steel Treater." This paper brought forth many interesting points which proved to be of decided value to both the technical and practical men who had the privilege of hearing Prof. Ellis' address. Following the presentation a lively and interesting discussion ensued.

This meeting was the last one on the program for the year 1922-23.

TRI CITY CHAPTER

The Tri City chapter of the Society held its annual picnic at Linwood Resort, Iowa Shore west of Davenport, Saturday afternoon, June 23, 1923.

This picnic was certainly a decided success, there being the largest turnout for such an affair that had ever been held by the chapter. To be sure, the thermometer registered 96, but all members were on hand to enjoy the eats, drinks and smokes furnished by the chapter's picnic committee.

One of the main features of the picnic was a ball game between the Metallurgists headed by Put Putnam and the Tool Hardeners headed by C. U. Scott. The game was a good one but the Metallurgists succumbed to the Tool Hardeners, the score being 177 to 176. Everyone had a most enjoyable time and are looking forward to the next picnic a year hence.

In addition to the list of officers elected at the meeting of the chapter, as published in the June issue of TRANSACTIONS, the following members will serve on the executive committee for the ensuing year: Harold Brown, Reynolds Engineering Co., Moline, Ill.; C. H. Burgston, Deere & Co., Moline, Ill.; R. A. Heeschen, Zimmerman Steel Co., Bettendorf, Ia.; R. Henry, Moline Plow Co., Tractor Works, Rock Island, Ill.; J. F. Lardner, Deere & Co., Moline, Ill., and H. O. Koehler, White Lily Mfg. Co., Davenport, Ia.

WASHINGTON CHAPTER

The chapter held a meeting on May 25th at which time the election of officers for the coming year took place, the following members being elected: chairman, Jerome Strauss, vice-chairman, W. F. Graham, secretary-treasurer, J. S. Vanick. H. J. French was elected as chairman of the Meetings and Papers committee.

OBITUARY

It is with deep regret that we have to report the untimely death of John Everett Rogers, secretary of the A. Hankey & Co. Inc., of Rochdale, Mass. Mr. Rogers died the seventh day of May and in his death the Society lost an enthusiastic worker and friend.

Mr. Rogers was one of the early members of the Steel Treating Research Society, and was instrumental in the formation of the Worcester Chapter, in which he served faithfully as Secretary-Treasurer for two years and later as its Chairman. At the Indianapolis Convention "J. E." was chairman of the delegate's session and took an active part in the preparation of the program.

The enthusiam Mr. Rogers placed in his work, the cordial good will and ready assistance to all of the members and his

JOHN E. ROGERS

general capability endeared him to the members of the local chapter and to all people who were fortunate enough to have come in contact with him. He will be missed.

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective

NEW MEMBERS

ACKER, SIDNEY A., (Jr-6), 1428 6th St., S. E. Minneapolis, Minn.
ADRIANCE, E. F., (M-5), 173 Santa Fe Ave., Huntington Park, Cal.
ALLAN, JAMES, (M-4), 1115 El Molino St., Los Angeles, Cal.
ARDAHL, EINAR, (Jr-5), 1907 16th St., Moline, Ill.
ARMOUR, JAMES D., (M-5), Union Drawn Steel Co., Beaver Falls, Pa.
ARNESS, W. B., (M-6), 2627 Nicollet Ave., Minneapolis, Minn.
ATKINS, CLARENCE B., (M-6), 129 Woodland St., Bristol, Conn.
AUSCHULTZ, L. T., (M-5), 1019 Blackadore Ave. E., Pittsburgh, Pa.
BAKER, CHAS. K., (A-6), 70 Mathewson St., Providence, R. I.
BELLIS, CLIFFORD B., (M-6), Blake & Valley Sts., New Haven, Conn.
BETTINGER, H. B., (A-6), 185 Devonshire St., Boston, Mass.
BICKNELL, ARTHUR B., (Jr-5), 2441 13th Ave., Moline, Ill.
THE BRISTOL CO., (S-6), Att: H. H. Bristol, V. P., Waterbury, Conn.
CHASE, RODNEY, (S-6), Chase Metal Works, Waterbury, Conn.
CLARK, RICHARD G., (M-6), New Departure Mfg. Co., Bristol Conn.
CLARK, WM. E., (A-6), Room 2-220 Gen'l. Motor Bldg., Detroit, Mich.
COLE, WILLARD W., (A-3), % So. California Iron & Steel Co., Los Angeles, Cal.
COLLINS CO., THE, (S-6), Collinsville, Conn.
COLWELL, DONALD L., (M-4), 5312 Pensacola Ave., Chicago, Ill.
COOLEY, W. S., (M-3), 1156 E. Calvert St., South Bend, Ind.
CRUM, B. M., (M-6), The Stanley Works, New Britain, Conn.
DALEMETER, VERNON, (M-5), Union Tool Co., Torrance, Cal.
DONNELLY, JAMES F., (M-5), 470 Vanderbilt Ave., Brooklyn, N. Y.
DULEY, W. H., (A-6), 1732 No. Adams Street, South Bend, Ind.
DUNBRACK, N. K., (M-5), 108 Alder Street, Waltham, Mass.
EDWARDS, W. H., (S-5), Edwards Iron Works, 2101 S. Main St., South Bend, Ind.
FICK, JOHN EDW., (M-6), Timken Roller Bear. Co., Canton, Ohio.
FURGASON, CLYDE A., (M-6), American Gear & Mfg. Co., Jackson, Mich.
FITZHUGH, JAMES M., (M-3), % Lewellyn Iron Works, Torrance, Cal.
FROMME, C. H., (M-4), 635 W. 35 Place, Los Angeles, Cal.
GEE, HARRY, (M-6), Dodge Brothers, Detroit, Mich.
GERMOND, R. C., (M-6), The Stanley Works, New Britain, Conn.
GOEDECKE, M., (A-6), 79 Woodruff Ave., Brooklyn, N. Y.
GOODYEAR, HARRY G., (M-4), 93 Richards Place, West Haven, Conn.
GRANGER, EDW. G., (M-6), 11 Sherman Street, Bristol, Conn.
HICK, GEO. H., (M-6), The Stanley Works, New Britain, Conn.
HULL, J. E., (M-4), P. O. Box 1318, Providence, R. I.
HUMPHREYS, E. T., (S-6), Seymour Mfg. Co., Seymour, Conn.
HYATT, M. V., (M-6), Fleetwood, Pa.
IRWIN, H. W., (Jr-4), 26 Villa Place, St. Thomas, Ky.
JACKSON, J. MILTON, (M-2), 1233 Lakewood Blvd., Detroit, Mich.
JOHNSON, JOHN, (M-6), The Whitney Mfg. Co., Hartford, Conn.
JOHNSTON, R. A., (A-3), Weherall Bros. Co., Albany St., Cambridge, Mass.
JOHNSON, WALTER L., (A-5), 420 So. San Pedro St., Los Angeles, Cal.

KUCHNEL, A. W., (M-3), 1429 E. Lombard St., Davenport, Iowa.
KYTE, HERBERT W., (M-4), 20 Carnegie Ave., East Orange, N. J.
LANDON, JUDSON P., (M-5), 72 Hart Street, New Britain, Conn.
LANTZ, WM. F., (M-5), 539 East North Street, Bethlehem, Pa.
LARSON, GODFREY, (M-12), 618 36th St., Rock Island, Ill.
LEETES, ERNEST, (M-4), 2514 Belvidere Ave., Detroit, Mich.
LOWMAN, M. C., (M-3), General Petroleum Corp., 2525 E. 37th St., Los Angeles, Cal.
THE MARLIN FIRE-ARMS CORP., (S-5), New Haven, Conn.
MARSH, L. S., (M-5), Inland Steel Co., 1st Natl. Bank Bldg., Chicago, Ill
McCHESNEY, CHAS., (M-4), 1409 Commonwealth St., Allston, Mass
MEAD, E. A., (M-5), 484 Beacon Street, Boston, Mass.
MOLINE BODY CORPN., (S-6), % Mr. L. F. Sickler, Moline, Ill.
NUSBAUM, J. E., (M-5), 1429 E. Marquette Rd., Chicago, Ill.
PARKER, FORREST S., (M-6), Saco-Lowell Shops, Lowell, Mass.
ROBBINS, M. T., (M-6), The Bellis Heat Treat Co., New Haven, Conn.
SCHIELE, GEO., (M-6), 3925 Forest Ave., Norwood, Cincinnati, Ohio.
SCOTT, CLIFFORD W., (M-4), 1510 1st Street, Rock Island, Ill.
SIMPSON, HARRY E., (M-6), 266 West Street, Bristol, Conn.
SOLOVIEFF, NICHOLAS, (Jr-5), Hastings St. & W. Cherry Lane, Baldwin, L. I., (N. Y.)
STANLEY WORKS, (S-6), New Britain, Conn.
STRATTON, SAMUEL S., (A-5), 102 Purchase St., Boston, Mass.
SULLIVAN, LEO D., (A-2), 4843 Bellevue Ave., Detroit, Mich.
TEUBER, CHAS. F., (A-3), Peoples Gas Lt. & Coke Co., 122 S. Mich. Ave., Chicago, Ill.
THELANDER, C. A., (M-2), 803 2nd Ave., Rockford, Ill.
THOMPSON, M. L., (Jr-5), 1164 22nd Street, Moline, Ill.
THURBER, ARTHUR E., (M-4), Oneida Community Ltd., Oneida, N. Y.
TRANTIN, JR. J., (M-6), % Pettibone-Milliken Co., 4710 W. Division St., Chicago, Ill.
TUTHILL, W. C., (M-5), National Machinery Company, Tiffin, Ohio.
WAGNER, JOHN, (M-1), 614 Genessee St., Flint, Mich.
WALKER, WM., (M-6), 91 Coburn Street, Lowell, Mass.
WEISE, ALFRED M., (M-6), 19 Wall Street, New Haven, Conn.
WETHERBEE, CHAS. F., (M-6), Marlin Fire-Arms Corpn., New Haven, Conn.
WILCOX, R. H., (A-5), 1482 Lee Place, Detroit, Mich.
WILLIAMS, ROBT. S., (M-5), Mass. Inst. of Technology, Cambridge, Mass.
WOODSIDE, ROBT. A., (Jr-4), 617 13th Avenue, Munhall, Pa.
ZIMMERMAN STEEL CO., (S-6), Bettendorf, Iowa.
ZINK, E. P., (M-4), 327 Mt. Vernon Ave., Detroit, Mich.

CHANGES OF ADDRESS

AFFLECK, G. S., from 278 E. Canfield Ave., to % Dodge Bros., Detroit, Mich.
ANDERSON, ARVID, from Pratt & Whitney Co., to 394 New Britain Ave., Hartford, Conn.
ARCHEA, WALTER D., from 621 Crown St., Cincinnati, O., to 2341 Kenilworth Ave., Norwood, Cincinnati, Ohio.
ARTHUR, WALTER, from Texas Christian Univ., Ft. Worth, Tex., to Reeds, Mo.
BECKER, CHAS. R., from 631 Canton St., to 3030 Collingwood Ave., Detroit, Mich.
BEDWORTH, R. E., from % Westinghouse Research Lab., E. Pittsburgh, Pa., to Westinghouse Elec. & Mfg. Co., 165 Broadway, New York, N. Y.

BLUMBERG, HARRY, from 1424 W. 14th St., Chicago, Ill., to 2414 Auer Ave., Milwaukee, Wis.

BLYTHE, W., from 1962 Tuxedo Ave., Detroit, Mich., to 412 Brookside Dr., Birmingham, Mich.

BOHNER, C. M., from 216 Myrtle Place to 143 Hall Street, Akron, O.

BOYLE, J. D., from Continental Motors Corpns., Muskegon, Mich., to 1131 Newport Ave., Detroit, Mich.

BRAY, H. M., from 324 4th Avenue, Pittsburgh, Pa., to Colonial Steel Co., 213 West Lake Street, Chicago, Ill.

BRUCE, Y. J., from 34 Chittenden Ave., Columbus, O., to 94 S. Linwood Ave., Crafton Branch, Pittsburgh, Pa.

BURROWS, C. W., from 17 Nevada St., Newark, N. J., to 154 Ogden Ave., Jersey City, N. J.

CLARK, REGINALD, from 175 Norwalk Ave., Buffalo, N. Y., to Western Drop Forge Co., Marion, Ind.

COLCORD, C. A., from 1951 W. Madison St., Chicago, Ill., to 623 Layton Ave., Cudahy, Wis.

COWELL, W. T., from 1851 Chase Ave., Cincinnatl, O., to Reed & Prentice Co., Worchester, Mass.

CROSSMAN, L., from 285 Main Street, Bristol, Conn., to 15 Amherst, Springfield, Mass.

CROWLEY, D. J., from 823 Dime Bank Bldg., Detroit, Mich., to Wayne, Michigan.

DODGE, RALPH, from 810 Park Ave., Syracuse, N. Y., to 126 Peck Ave., Syracuse, N. Y.

DOERR, PAUL C., from 54 Meridith St., Springfield, Mass., to Kenwood Ave., Delmar, N. Y.

GREEMAN, O. W., from 24 Hendricks Place to 1933 College Ave., Indianapolis, Ind.

HICKOX, WILL, from 743 32nd Street, to 661 Jackson St., Milwaukee, Wis.

HILDORF, WALTER, from 521 E. Main Street to 532 Park Lane, East Lansing, Mich.

HOBBS, D. B., from 2210 Harvard Ave., to 3790 Archwood Place, Cleveland, Ohio.

JACOBUS, L. C., from Tate Jones & Co., Pittsburgh, Pa., to 808 Beaver Street, Sewickley, Pa.

JOHNSON, WM. R., from 134 Juneau Ave., Apt. "C," to 142 27th St., Milwaukee, Wis.

KURRASH, C. A., from 9828 Winston Ave., Chicago, Ill., to 92 Peterboro St., Detroit, Mich.

LARDNER, JAMES F., from John Deere Plow Works to 1729 11th Ave., Moline, Ill.

LOEBELL, H. O., from A. L. Doherty Co., 24 State St., to 8-10 Bridge Street, New York City, N. Y.

LOTTES, W. G., from Steel Expert Mfg. Dept., International Harvester Co., Harvester Bldg., Chicago, Ill., to 213 Lake Street, Madison, Wis.

McAMBER, M. F., from 6340 Douglas Ave. E., to 924 Maryland, E. Liberty St., Pittsburgh, Pa.

McGAHEY, W. E., from 105 Highland Ave., Covington, Va., to 1104 145th St., East Chicago, Ind.

McMILLEN, R. H., from 134 Virginia Ave., Aspinwall Sta., to 1115 King Ave., Pittsburgh, Pa.

MOHR, E. J., from 1903 Chambers St., to 757 27th Street, Milwaukee, Wis.

PENROD, W. W., from 1556 Cohassett Ave., Lakewood, Ohio, to % International Harvester Co., Milwaukee, Wis.

PERRY, L. C., from Scullin Steel Co., 6700 Manchester Ave., to 4950 Forest Park Blvd., St. Louis, Mo.
PFEIL, WALTER H., from Box 1103, East Chicago, Ind., to Standard Engr. Co., Elwood City, Pa.
RICHARDSON, G. A., from Midvale Steel Ordnance Company, 1630 Widener Bldg., to 27 E. Springfield Ave., Chestnut Hill, Philadelphia, Pa.
RIMBACH, RICHARD, from 327 McKee Place, Pittsburgh, Pa., to 244 East 30th St., New York City, N. Y.
ROHLAND, L. E., from Poldi Steel Corp. of America, 115 Broadway, to 151 Baick St., New York City, N. Y.
ROOT, H. H., from 146 33rd Street, Whitestone Landing, N. Y., to 126 Lathrop Street, Beverly, Mass.
SCHEID, A. J., Jr., from 707 Delaware Street, Minneapolis, Minn., to 634 28th Street, Milwaukee, Wis.
SCHULTZ, HARRY, from 728 15th St., S. E., Washington, D. C., to 1004 Braddock Ave., Swissvale, Pa.
SIEGMEIR, ALBERT, from 5717 S. Aberdeen Street, to 5837 Mozart Street, Chicago Lawn Station, Chicago, Ill.
STERNAGLE, C. A., from Colonial Steel Co., 213 W. Lake St., to 7011 Chappell Ave., Chicago, Ill.
THOMAS, C. P., from 1107 Lee Street to 910 Vine Street, Lansing, Mich.
WACKER, J. W., from % Chain Belt Co., to Sterling Tool & Mach. Co., Wilwaukee, Wis.
WILLIAMS, D. R., from 262 Palace Theatre Bldg., to 610 Sycamore St., Milwaukee, Wis.
WOODWARD, E. L., from 2201 Woolworth Bldg., to 30 Church Street, New York City, N. Y.
ZIMMERLI, F. P., from 459 Hancock W., to 1585 Delaware Ave., Detroit, Mich.

MAIL RETURNED

GLAB, PETER, 502 East Jefferson Street, Syracuse, N. Y.
PUSITZ, L., 3514 28th Street, Detroit, Mich.
WARD, W. J., Union City, Pa.
WOLF, ERNEST, Lewis Institute, Chicago, Ill.

QUESTION BOX

Concluded from Page 90

lines of weakness and cleavage planes, and consequently is more economical in the expenditure of energy. High velocity blows have just the opposite effect; the plastic steel presents a greater resistance to outward flow, and fills up the die from a smaller bar and with a smaller fin.

A word of warning may be given with regard to the dies. The effect of high velocity blows is likely to be more local, therefore deep impressions should have plenty of material around them.

QUESTION NO. 85. *What is the best method of preventing carburization in holes, or in the bore of parts to be case hardened?*

EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

Important Notice.

In addressing answers to advertisements on these pages, a stamped envelope containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITIONS WANTED

WANTED—POSITION AS SUPERVISOR of a heat treating department. Have had 12 years experience in heat treating, tool and die hardening. Address 4-5

WANTED—POSITION AS HARDENER. Have had 5 years practical experience with a large firm in general hardening of both carbon and high-speed steel as well as carburizing. Fully competent. Age 35. Married. Address 4-10.

METALLURGIST WITH 8 YEARS EXPERIENCE in the analysis of ferrous and nonferrous metals, physical testing, metallography and heat treatment of plain and alloy steels, desires responsible position in laboratory of well established concern. Address 4-15.

POSITION IS DESIRED AS FOREMAN OF HEAT TREATING DEPARTMENT. Seven years of high grade experience with carbon, high speed, and alloy steels, covering all phases of heat treating. Best references. Address 4-20.

POSITION WANTED IN METALLURGICAL LABORATORY. Seven years of high grade experience in metallographic testing, research work and experimental heat treating; also pyrometry technical training. Best references. Address 4-25.

EXPERIENCED TOOL HARDENER would like a position in or around New York. Has had 11 years experience. Can harden and carburize all kinds of steel. Can give first class references if desired. Address 4-30.

AS WORKS SUPERINTENDENT with 16 years of high grade experience in all branches of tool and metal parts manufacturing. Can assure maximum quality production at a minimum cost. Best of references. Address 4-35.

ASSISTANT METALLURGIST. Ten years practical experience in heat treating department and laboratory of several well known concerns. Boston district preferred. Salary $150.00 per month. Married. Address 5-10.

METALLURGIST—1916 Graduate with six years experience as chief chemist and chief metallurgist. Thoroughly familiar with ferrous and non-ferrous analysis, metallurgy, metallography and physical treatment. Has had also good production experience, having had charge at Steel melting and heat-treating departments. During past year has been metallurgist for a Government Arsenal, in charge of ferrous and non-ferrous research and testing. Available at once. Address 6-1.

POSITION WANTED

FOUNDRY CHEMIST AND METALLURGIST, capable of supervising the manufacture of steel, malleable and gray iron castings. Expert on converter steel practice, heat treatments and facing sands. Has had 15 years experience. Address 6-5.

CHEMIST AND HEAT TREATER desires a position in laboratory or heat treating department, experienced in chemical and physical testing of iron and steel and other alloys. Eastern location preferred. Reasonable salary. Address 6-10.

POSITIONS OPEN

SALES ENGINEERS WANTED young single men for positions as sales and service engineers, calling on superintendents, managers, engineers, chemists and metallurgists, for manufacturers of well known high-grade automatic electrical and temperature equipment, extensively used in factories, power plants, chemical and industrial works. Knowledge of physics and elementary electricity required. Graduates of technical schools preferred. Candidates must be free to travel in the great manufacturing and industrial districts. Young men of good address and ability to talk convincingly to engineers wanted, but no previous experience demanded. Write describing education and earning experience, if any, and stating age and salary desired. Address 6-15.

POSITION OPEN IN GEAR PLANT located in Berkeley, California for practical heat treatment foreman who is famiiar with carburizing and general heat treatment details. Expert metallurgist not a requirement but a man possessing thorough knowledge of the heat treating game. Address Johnson Gear Company, 232 Rialto Building, San Francisco, California giving full information and salary required.

DIE BLOCK DESIGNER and hardener wanted by an eastern concern who manufacture die blocks. This position offers an excellent opportunity for one who has had experience in both the designing and hardening of blocks. State experience and qualifications. Address 4-40.

WANTED A THOROUGHLY COMPETENT, energetic man, preferably techical, to sell pyrometers, regulators, etc., in Michigan District. Only high grade men who can produce results need apply. Give present employment, age, married or single, training, references, and income expected. Address 5-5.

Items of Interest

WE WISH to call your attention to the fact that there is published in this issue of the TRANSACTIONS a list of hotels in Pittsburgh, and inasmuch as the hotel accommodations in that city are somewhat limited, we would suggest that you immediately turn to the list of hotels and select the one where you desire to be located during the A. S. S. T. convention and forward your reservation at once observing precautions given in the foreword.

E. F. Cone, associate editor of *Iron Age* has been appointed by the board of directors to fill the vacancy of manager of the American Electro Chemical Society caused by the election of A. T. Hinckley to the presidency.

William C. Hartman, formerly with the Bethlehem Steel Company, Bethlehem, Pa., has served his connections with the company and is now connected with the Union Tool Company at Torrance, California, in charge of their heat treatment department.

A large contract for furnace equipment recently was booked by F. J. Ryan & Co., Wesley building, Philadelphia, from the Hupp Motor Car Co., for equipment for a complete new heat treating plant to be erected at Jackson, Mich. In this plant will be installed two large automatic continuous furnace units, each unit composed of a heating, quenching, and drawing unit, each 75 feet in length. There also will be one automatic continuous normalizing furnace, a heat treating furnace, one cyanide treating furnace, one standard hearth type treating furnace, quenching oil, cooling systems and water cooling systems for normalizing temperature of quenching oil.

Frank O. Hoagland, for several years general manager of the Reed-Prentice Co., Worcester, Mass., has resigned to accept a position in the mechanical department of the Saco-Lowell Shops, Boston and his duties will be taken over by J. Verner Critchley, who recently was elected president of the company.

William T. Cowell, former assistant works manager of the Lodge & Shipley Machine Tool Co., Cincinnati, has been appointed works manager

of the Reed-Prentice Company and Frederick W. McIntyre, general sales manager of the latter organization has been made assistant to the president.

George Satterthwaite has resigned as vice president of the Penn Seaboard Steel Corp., and Tacony Steel Co., to become associated with Henry Disston and Sons, Inc., Philadelphia.

Mr. Satterthwaite has had a wide experience in the production of high grade steels. He was for a number of years connected with the original Midvale Steel Co., and the Midvale Steel & Ordnance Co. As general superintendent of the Nicetown Works, Mr. Satterthwaite was in direct charge of all manufacture, including the production of Midvale's numerous alloy steels, and ordnance material for American and foreign governments. In 1917 he resigned as general superintendent of the Nicetown plant to become vice president and general manager of the Tacony Ordnance Corp., a company which erected and equipped in record time as a self-contained plant for the manufacture of howitzer and field gun forgings. Following the armistice and the cessation of ordnance manufacture, the Tacony Ordnance Corp., consolidated with the Tacony Steel Co., Mr. Satterthwaite continuing as vice president of the combined companies. In 1919 Tacony merged with the Penn Seaboard Steel Corp., and Mr. Satterthwaite was elected to the position he has just vacated, that of vice president in charge of operations at the Penn Seaboard-Tacony plants in Tacony, Philadelphia, New Castle, Delaware, and Chester, Pennsylvania. He will continue as a director of both Penn Seaboard Steel Corp. and the Tacony Steel Co. Mr. Satterthwaite is a graduate of Swarthmore college and a resident of Huntington Valley, Pa.

Frank O. Wells, of the F. O. Wells Co., Greenfield, Mass., is president and chairman of directors of the Wells corporation, Greenfield, recently formed by the consolidation of three tool industries, including the Wells company, the American Tap & Die Co., and the Williamsburg Mfg. Co. Mr. Wells is a pioneer in the tap and die industry, having begun 49 years ago as a workman in the plant of Wiley & Russell, Greenfield. During the World War he was placed on the National Screw Thread commission which was sent to Europe to negotiate for a standard screw thread. In 1922 he took a leading part in organizing the Greenfield Tap & Die Corp., of which he was president until his resignation in 1919. He is a charter member of the National Screw Thread commission.

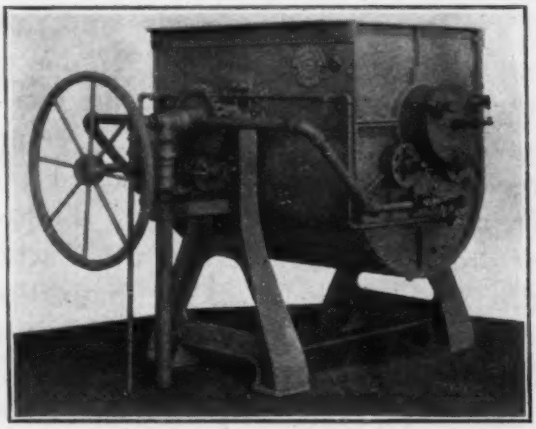
Mr. Wells is a member of the Springfield chapter of the American Society for Steel Treating.

For carburizing certain classes of light material, fairly uniform in size and shape, the Rockwell tilting revolving furnace offers advantages over the ordinary packing-pot method with a stationary furnace.

The pieces to be carburized are charged loose with carbonizing compound in the retort, which is continuously revolved while under heat.

The furnace may be tilted backward to facilitate charging and tilted forward for discharging. It is in horizontal position while heating, but the retort may be rotated while the furnace is in any position.

The slow turning and mixing action of the pieces and carburizing compound in the retort tends to uniformity of heating and carbonizing by ex-



posing each piece substantially to the same temperature, for the same time and in the same manner. The continual agitation of the charge also tends to decrease the time ordinarily required to raise the temperature of the material at the center of the mass and to decrease the time required to obtain a desired depth of case. This minimizes the variation in quality due to higher temperature, longer time of exposure of material at the outside of the mass, and variations due to irregular packing, which frequently occur in ordinary pot practice.

In additin to the advantages in uniformity of temperature, time of heating and uniform depth of case, there are other advantages in economy of operation. The time and labor of packing the material is less than in the ordinary pot practice. There is a saving in the cost of pots per pound of material carburized, the labor of handling them, and the heat that is generally lost in cooling, as the retort is not removed from the furnace and is maintained at a comparatively uniform temperature.

Oil, gas or electricity may be used for heating, the choice depending upon the nature of the process, manufacturing conditions and relative cost of available forms of heat energy.

The furnace is made in two standard sizes: one with a retort 12 inches